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Reliability Prediction Studies on Electrical Insulation: Navy Summary Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Reliability prediction studies on magnet wire, motor insulation systems, and aerospace wires, conducted over a span of 20 years, are summarized. Emphasis is on thermal aging of insulation, including problems in development of evaluation methods and equipment, analysis of data, and development of Navy and industry standards. The usefulness of truncating data to save time is discussed, and truncation is found to save up to 20% in testing time. New and improved equipment is described, including a novel

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condensation chamber that provides a controlled wet humidity cycle during functional evaluation of insulation systems. A recommendation to adjust the Navy's 40 000-h lifeline benchmark is made, on the basis of recent data and field experience. Regression analysis data for 254 magnet wire twist tests and 62 insulation system motorette tests are documented.

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RELIABILITY PREDICTION STUDIES ON ELECTRICAL INSULATION: NAVY SUMMARY REPORT

INTRODUCTION

The Navy's combat effectiveness depends on the reliability of the equipment in its vessels. The reliability of electrical equipment can be increased by overdesigning and by decreasing operating temperatures. This might be practical in land installations where weight and size are unimportant. On a ship, the resulting increased weight and size would decrease the combat effectiveness of the vessel. Thus, equipment designers must reduce weight and bulk and also maintain and even improve reliability. This could be achieved with the improved synthetic materials which were being generated by industry at a considerable rate, during the post-World War II period. While this generation of materials displayed superior characteristics, they had no pedigree to assure long life in use.

The Navy, faced with the responsibility of increasing the combat effectiveness of its vessels, embarked on a major study of the aging properties of electrical insulating materials and systems. This involved the development of evaluation techniques for comparing the expected lives of new insulations. This program was initiated at the Naval Research Laboratory in 1952. Around 1965, when techniques for evaluating electrical components and systems were being firmed, much of the evaluation program was transferred to the Navy Ships Research and Development Laboratory.

This research, while it benefited the Navy, also had considerable impact on national and international standards. To illustrate a few highlights, the data generated by the Navy confirmed the thesis that thermal aging was governed by the chemical laws known as the Arrhenius relations. The influence of electrical and mechanical stresses and of humidity were demonstrated. In this connection, NRL established the level of mechanical stress that has been universally adopted in the applicable standards. One of the problems was the level of the lifeline at which temperature ratings could be compared for various insultations. The Navy provided much of the long-term temperature-life data needed for establishing this standard. Humidification, which was used as a searching agent for failures, was difficult to standardize. However, when the IEEE 117 Test Procedure was being developed the Navy took the initiative to investigate this factor and produced a technique and a chamber design that were incorporated in the procedure.

Over the years, all thermal aging data were universally treated as an Arrhenius relationship. However, the question arose, in connection with aircraft wire aging, of whether life predictions could be made when the operating temperatures were variable. This was demonstrated to be possible by integrating the effects dictated by the Arrhenius laws. In addition, a significant contribution was made to the economics of the thermal

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evaluation procedures. In general, a year of experimental time is required to obtain a life-vs-temperature characteristic curve. A detailed statistical analysis validated truncated data techniques as applied to thermal aging; this substantially reduced testing time.

ORIGIN OF THERMAL CLASSIFICATION AND EVALUATION

The need to know the effects of temperature on electrical insulation was first analyzed and discussed when Steinmetz and Lamme published their 1913 paper, "Temperature and Electrical Insulation" [1]. This classic paper not only reflects the accepted concepts of their day but also introduces the theory that insulation deteriorates with time at certain temperatures.

At that time insulating materials were classified in three main categories, known as classes A, B, and C, according to the general compositions of the materials. Class A included fibrous materials such as paper and cotton, along with most of the natural oil resins and gums. Class B included heat-resistant materials like mica, asbestos, and equivalent refractory materials, frequently used in combination with other binding materials. The fireproof or heatproof materials such as mica, "so assembled that very high temperatures do not produce rapid deterioration," were considered Class C.

In 1913 the accepted general temperature ranges for the three classes were

Class A — to 90°C
Class B — to 125°C
Class C — to 150°C to point of incandescence.

Figure 1 is a general guide temperature-life curve for Class A insulation taken from the 1913 Steinmetz and Lamme paper. It illustrates the generally prevailing belief that electrical insulation suffered insignificant deterioration below 90°C but that above 100°C the rate of deterioration increased rapidly until 125°C, above which life was shortened to a few weeks. In other words, it was thought that aging did not begin until a definite temperature had been exceeded.

It is interesting that it was then also thought that if the insulation was cooled to room temperature between duty heat cycles, the actual hours of accumulated thermal aging would be decreased (as compared to continuous duty) because the insulation would have a chance to "recover."

By the late 1920s a higher figure, 105°C, was taking hold as the representative temperature for Class A materials, although V. M. Montsinger in his 1930 paper, "Loading of Transformers by Temperature" [2], advocated a more conservative value of 95°C. In addition, Montsinger believed that the sole end-of-life criterion was mechanical failure of the insulation and that it was "hopeless to judge the rate of deterioration of insulation by its electrical strength." This idea stemmed from the belief that the electrical strength of insulation increased in general with age until the material actually cracked open. At the same time he introduced the idea that mechanical deterioration was a continuous reaction to temperature and that the rates could by some means be determined. This was in sharp contrast with Steinmetz, who held that no deterioration could occur below a critical temperature for the material.

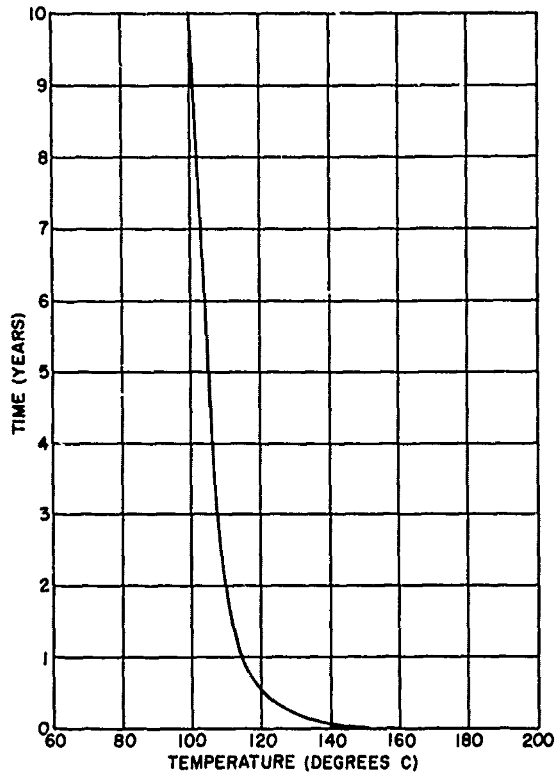


Fig. 1—Possible life-vs-temperature relationship of Class A insulation [1]

The accumulated data from his study suggested a general law for insulation aging that is represented by a straight line on semilog paper with a linear temperature scale. The curve was expressed by the equation

$$Y = Ae^{-mt}$$

where Y = life in years
A and m are constants that characterize the insulation
t = temperature in °C
e = base of natural logarithm.

This data, obtained over nine years, was on the tensile strength of paper, aged in oil and in air. A product of this milestone study of Montsinger's was a rough demonstration of what might have been called an "8- or 10-degree" rule. Additional data obtained during the subsequent years substantiated this rule, defining it as the "10-degree" rule. In effect, this empirical relation states that the thermal life of insulation is halved for each 10°C increase or, conversely, doubled for each 10°C decrease.

In the development of functional evaluation there has been and probably always will be one primary question: Have all the factors that produce measurable and significant changes in the life been properly included? Naturally, the purest form of functional evaluation would be the gathering of life data on the equipment itself when used under specific field conditions. However, this is impractical for two good reasons, namely time and expense. Yet a flood of new materials were becoming available, starting in the middle 1940s and increasing in volume through the 1950s.

Industry as well as the government realized that it was imperative to devise some means to evaluate functionally insulating materials and even insulation systems relatively quickly and at reasonable cost.

Thus, a new milestone had been reached as numerous laboratories engaged actively in a comprehensive program, embracing many approaches to the problem and eventually resulting in new test procedures. The Navy in particular had a compelling desire to move ahead in materials and insulation systems engineering, because of its urgent need for military specifications for purchasing these new materials. The first research to be performed was to investigate the effects of voltage, vibration, heat cycling, and humidity on the life of magnet wire insulation [3]. To this end, coils were wound with about 30.5 m (100 ft), of number 26 enameled magnet wire. Ten turns of wire of the same insulation were inserted at the center of the coil to provide (a) a known dielectric stress, (b) detection of insulation failure by current flow, and (c) measurement of temperature by resistance change. The coils were heated by circulating current through the main winding, in a constant ambient of 60°C. The assembled coils on the mounting rack are illustrated in Fig. 2.

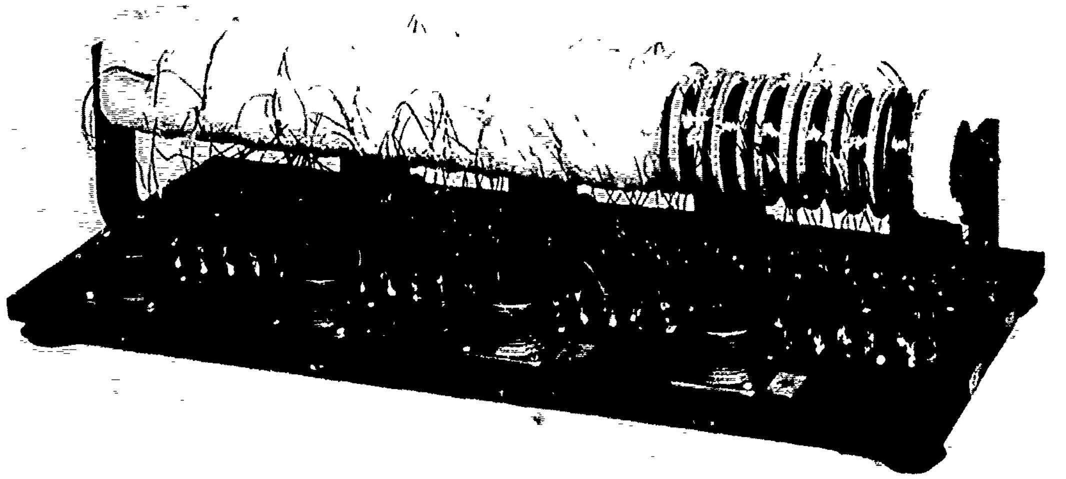


Fig. 2—Coil assembly showing asbestos wrapping and lead attachment

With the above experimental setup, the effect of voltage at 1 g, from 4.5 to 50 V, was first investigated. As in Fig. 3, there was a strong dependence of life on voltage at 160°C. The effects of vibration were determined at 35 V d.c., from 0 to 5 g at 160°C. Figure 4 shows the effect of vibration to be more dominant at higher values of g, but the spread in life data is much less.

During these early investigations by the Navy, industry was conducting parallel research to develop evaluation techniques. However, they were concentrating more on the development of test models to simulate magnet wire applications and complete insulation systems for electrical rotating machinery.

By 1952, Dexter was experimenting with modifications of the standard NEMA magnet wire twist sample formerly used for voltage breakdown testing. A generous amount of thermal aging data were already being accumulated using various test variables including temperature and voltage stress, which he reported in 1954 [4]. This together with the work of many others, including the members of AIEE committees, constituted the background experience that later made such classic documents as AIEE 57, 65, 510, and 511 possible.

Simultaneously, Cypher and Harrington were developing a test model of a motor that would be suitable for evaluating functionally an insulation system without the expense of full-size motors [5]. Later these model motors were appropriately named "motorettes." This marked another milestone in the development of functional evaluation, as it paved the way to several other "model-ettes," among them the armette and formette. For several years the motorette went through development and design improvements but remained basically the same. Two of these improvements were rather significant. First, in a study by the Navy, it was found that the Class H terminal block was allowing excessive current leakage under high humidity; this was solved by substituting porcelain and standoff insulators. Second, an almost two-to-one savings of space and weight were realized when John Dexter's smaller motorette design was adopted; the current design is shown in Fig. 5.

During this time physicists and chemists such as Dr. Dakin were making a closer study of the basic phenomena of thermal aging of electrical insulation. In 1948, he published a paper [6] proposing a chemical rate theory interpretation of thermal deterioration. This was a logical proposal since the observed physical changes during the thermal aging are the results of internal chemical change. It not only provided a more satisfactory explanation, but also allowed a more correct coefficient of deterioration than was permitted by the 10-degree rule. This more descriptive relationship is

$$L = Ae^{B/T}$$

where T is the absolute temperature and A and B are constants determined by the activation energy of the particular reaction (or $\log L = \log A + B/T$). Thus, plotting the log of the life of the insulation against the reciprocal of the absolute temperature should produce a straight line. This relationship was generally confirmed except where second and higher order chemical reactions enter into the aging phenomena.

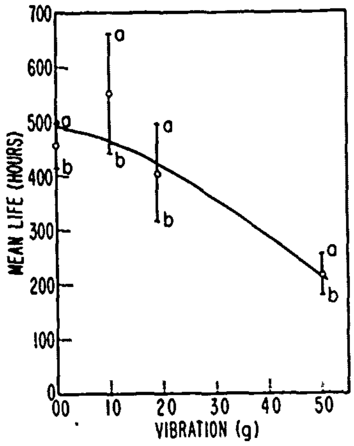


Fig. 3—Effect of voltage on life of Formex insulated coils at 160°C, 1.0-g vibration. Lines a-b represent 95% confidence interval

Fig. 4—Effect of vibration on life of Formex insulated coils at 160°C, 35 V d.c. dielectric stress. Lines a-b represent 95% confidence interval

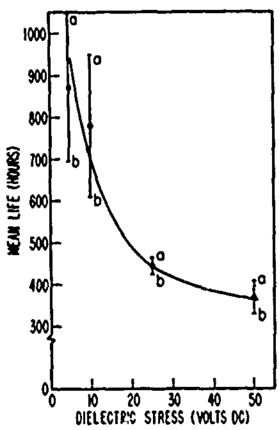


Fig. 5—Assembled motorette specimen with varnish treatment

PHILOSOPHY OF THERMAL CLASSIFICATION

During the past two decades much experimental work has been done to investigate the concept of temperature classification of magnet wire insulation, based on the possible linear relationship between the logarithm of life and the reciprocal of absolute temperature, as first observed by Dakin [6] to follow the Arrhenius chemical deterioration rate equation. Before this, the only available method was to assign temperature classifications based solely on the types of materials. This obviously left much to be desired.

The IEEE and ASTM, recognizing the significance and value of an evaluation method that was suitable for use in the laboratory under accelerated test conditions and yielded extrapolated data suitable for field classification purposes, sponsored development of the necessary test procedures. However, any accelerated laboratory test procedure for evaluating life-temperature characteristics of insulation can produce no more than comparative values on various insulations. Because of this limitation, one of the basic requirements is to establish hours-of-life reference values necessary to convert the laboratory life values of the various insulations into temperature ratings for field use. For example, insulation "A" has been proved through field experience to have earned a temperature rating of 105°C for a normal life expectancy of 15 to 20 years. This same insulation under laboratory test yields an extrapolated life of 5 years at 105°C. Based on this information, a newly developed insulation "B", which also yields 5 years of extrapolated life at 105°C, would also qualify for the same temperature rating. In like manner, if insulation "C" yields 5 years of extrapolated life at 130°C, it would qualify for a 130°C temperature rating.

It is only logical, then, that this reference life value should evolve from an insulation for which there is already adequate field experience. In addition to the field experience, adequate laboratory data must be available on the same insulation. Both industrial and Government laboratories have, over the past 20 years, accumulated much data on polyvinyl formal coated magnet wire, using IEEE and ASTM test procedures [7]. This wealth of laboratory data confirm actual field experience on the same wire and provide a basis for establishing reference lifelines for realistic temperature classification of film-coated magnet wires.

Most field experience with polyvinyl formal magnet wire has been with equipment impregnated with phenolic varnishes. This experience has firmly established a 105°C temperature classification for this wire. On the other hand, laboratory tests have indicated that at 105°C polyvinyl formal enameled wire, impregnated with the same varnishes, yields an average extrapolated life of 40 000 h (approximately 5 years). This value is based on many governmental and industrial laboratory tests with test temperature points ranging from 130°C to 200°C. It is recognized that due to many variables throughout the various laboratories, a wide range of extrapolated life values does exist. This range has a spread of from 30 000 h to as high as 90 000 h, depending on many such factors as the faithfulness to the test procedure, the test temperature range, and the particular phenolic varnish used. However, enough data were on hand at the time to set a minimum average life value of 40 000 h. The Naval Research Laboratory and Navy Ships Research and Development Laboratory have investigated well over 200 film and varnish combinations in the past 20 years, accumulating life-temperature data in many cases of well over 10 000 h at the lowest test temperature. Figures 6, 7, and 8 illustrate some of the NRL investigations that support the 40 000-h life figure for polyvinyl formal magnet wire impregnated with phenolic varnishes.

It is generally recognized that some manufacturers find the need to rate their film-coated magnet wires thermally, based on unvarnished temperature-life data. To make this kind of classification requires that an equivalent standard be established for unvarnished film-coated wires. The field-proven "benchmark" magnet wire (polyvinyl formal) yields an extrapolated life of 20 000 h at 105°C when tested unvarnished under the referenced test procedures, as illustrated in Fig. 9. Again, this figure was established by both governmental and industrial laboratory test and offers a basis for establishing a reference classification lifeline equivalent to the 40 000-h lifeline for varnished wires.

If equal thermal life could be expected from varnished and unvarnished film-coated wires, one common lifeline could be used for classification. However, experience has shown that this is not always the case. In a number of cases varnished wire yields a two-to-one, or better, life over unvarnished wire. See Figs. 9, 10, and 11 for typical examples. This two-to-one difference is significant in the case of polyvinyl formal coated wire (Fig. 9) inasmuch as it has been the one magnet wire (used in *varnish-impregnated* electrical equipment) with enough years of field experience to earn a rating of 105°C. Therefore the Navy, for one, has expected all new magnet wire coatings to meet the laboratory test benchmark reference lifeline of 40 000 h at the claimed temperature rating.

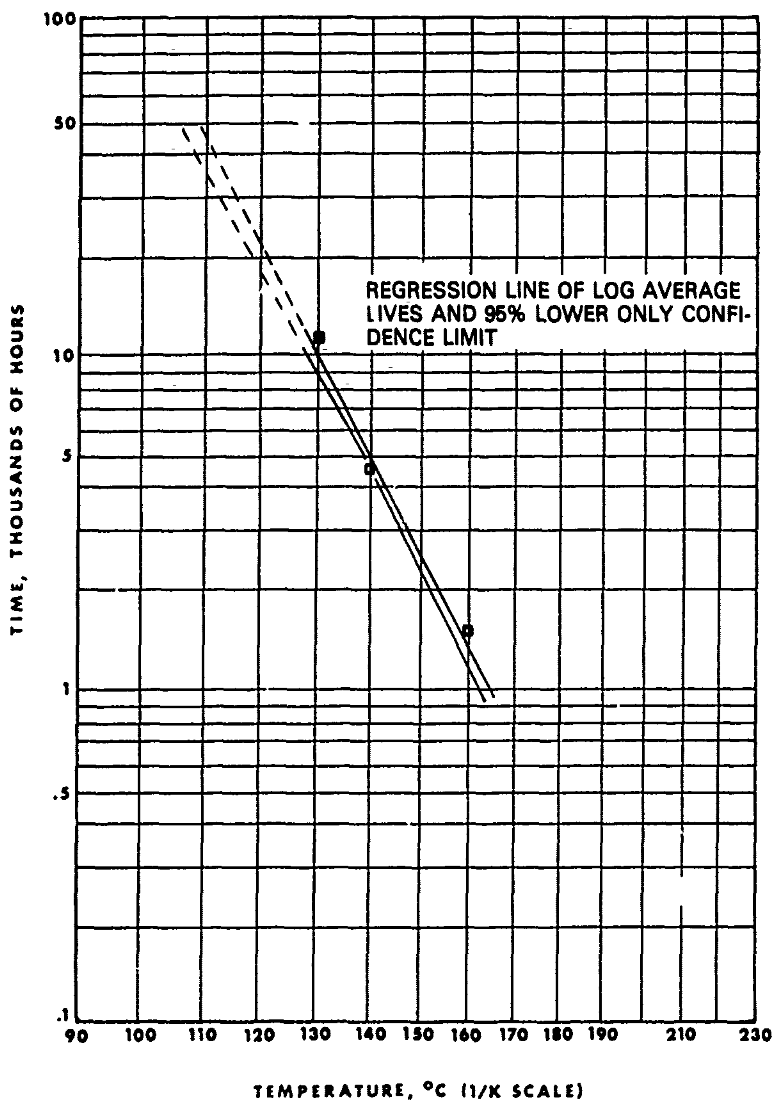


Fig. 6—Life-temperature characteristics of twist combination no. 9, polyvinyl formal magnet wire impregnated with phenolic-type varnish

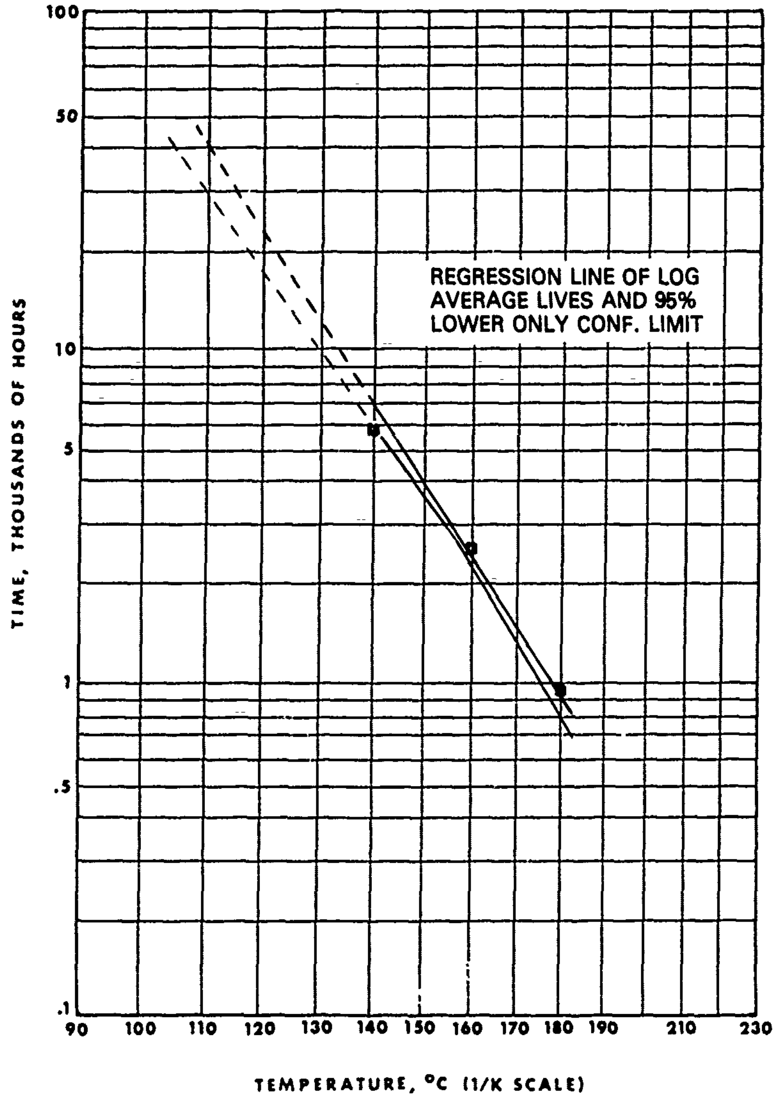


Fig 7—Life-temperature characteristics of twist combination no. 10, polyvinyl formal magnet wire with phenolic-type varnish

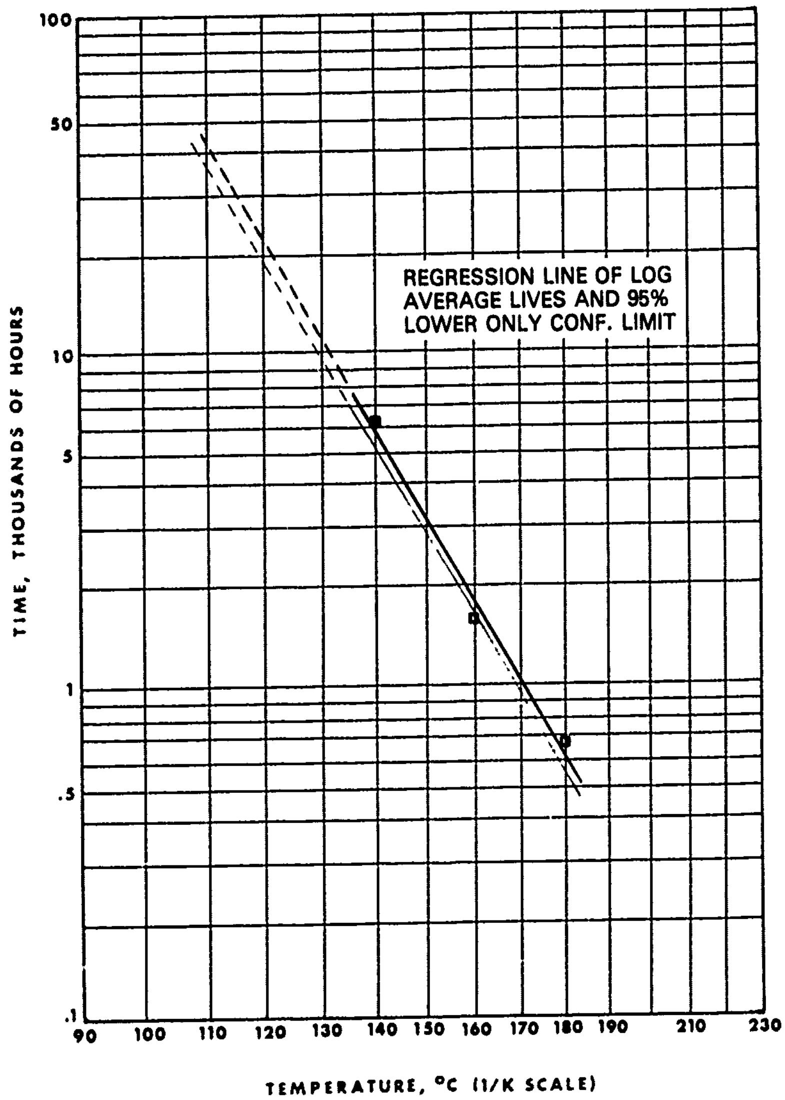


Fig. 8—Life-temperature characteristics of twist combination 135F, polyvinyl formal magnet wire with phenolic-type varnish

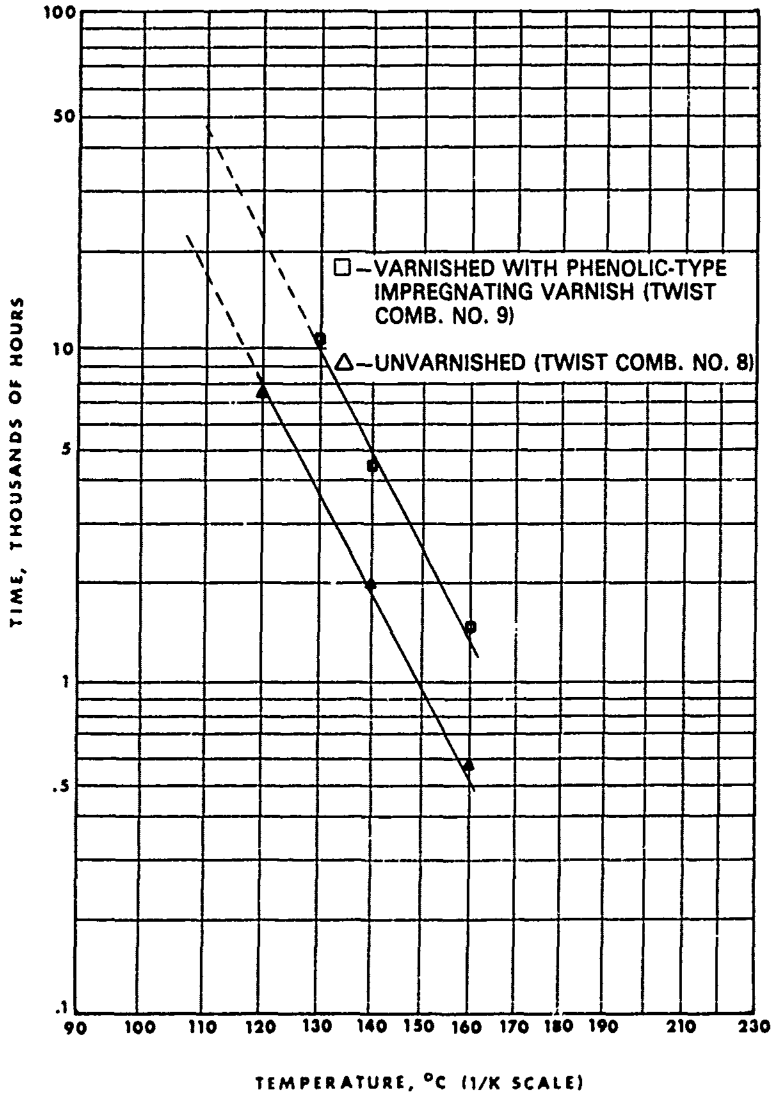


Fig. 9—Life-temperature characteristics of varnished and unvarnished polyvinyl formal magnet wire

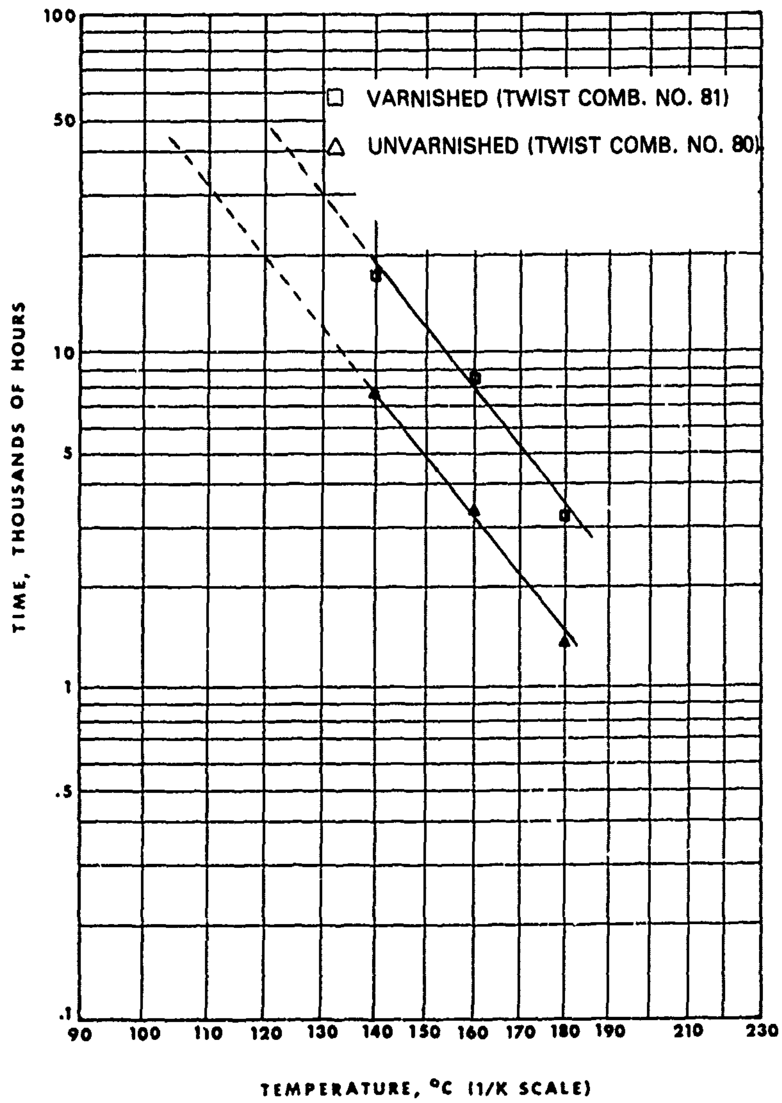


Fig. 10—Life-temperature characteristics of unvarnished and phenolic-varnished epoxy-overcoated magnet wire

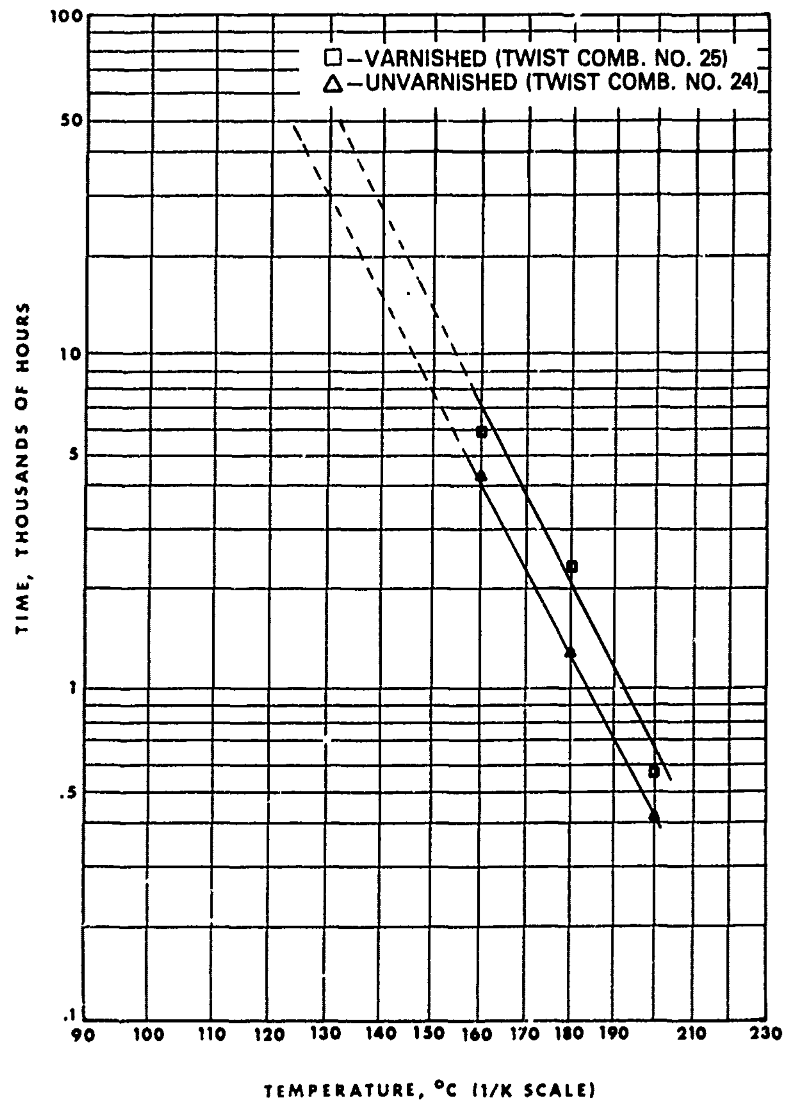


Fig. 11—Life-temperature characteristics of unvarnished and phenolic-varnished polyester-overcoated magnet wire

Many of the newer polyester-type magnet wires either yielded the same thermal life or were downgraded when treated with an impregnating varnish. Because of this, opinion was that the new film-coated magnet wires should be thermally rated using a common varnished-unvarnished lifeline of 20 000 h which had been established by unvarnished polyvinyl formal magnet wire at 105°C. All current evidence dictated a 40 000-h classification lifeline for rating film-coated magnet wires to be used in varnish impregnated rotating electrical equipment. The issue was debated for several years in an attempt to justify the varnished-unvarnished reference standard of 20 000 h. As newer, higher temperature magnet wires appeared on the market the Navy continued to rate them on the basis of the varnished polyvinyl formal field experience benchmark. In the meantime, however, industry was recommending a rating of about 10°C higher to their buyers than would be justified on the basis of the polyvinyl formal field experience benchmark.

After 15 years' use of the now common modified polyester (with and without top coat) magnet wire for use at 180°C, the evidence now points to a "satisfactory" field experience record at this operating temperature. A "satisfactory" record has been defined as one that does not include an undue number of negative reports or complaints against the product when used as recommended by the supplier. If the polyester-overcoated magnet wire is considered on the same basis as polyvinyl formal (as far as having earned a satisfactory field experience record is concerned), it likewise becomes a benchmark candidate. Fortunately, the Navy has adequate laboratory life-temperature data to set the lines for varnished as well as unvarnished tests. The data indicate that aging tests were conducted at low enough test temperatures to produce lives well above 10 000 h, and even 15 000 h in some cases. The state of the art in recent years has produced even more reliable aging data than was available when polyvinyl formal magnet wire was being laboratory evaluated for the purpose of setting benchmark values. When the laboratory test data for the modified polyester-overcoated magnet wire are plotted (Fig. 12), it can be seen that if the 180°C extrapolated operating temperature is considered, the reference lifeline becomes 20 000 h for the magnet wire when varnished with typical polyester varnishes used to impregnate rotating electrical equipment.

When the combined laboratory test data for the motorette systems employing the same modified polyester-overcoated magnet wire and class 155 varnishes are plotted (Fig. 13) a lifeline of 20 000 h yields 184°C, as compared to 182°C for the varnished magnet wire twist tests. This 2°C higher extrapolated temperature for the motorette tests provides a somewhat more conservative estimate for selecting 180°C as the appropriate qualifying temperature at 20 000 h. In considering this correlation between twist and moterette test data it should be noted that the motorette data were obtained using the Navy's version of the IEEE 117 Test Procedure which employs a humidity cycle of 100% relative humidity with no visible condensation. (Approximately half the life can be expected if 100% relative humidity with visible condensation is used, as stipulated in the IEEE 117 procedure.) It is also important to note that the motorette insulation systems tested were "supported" systems. This means that the phase and ground insulations support the magnet wire, allowing turn-to-turn first failures to reflect the life of the magnet wire component in the system.

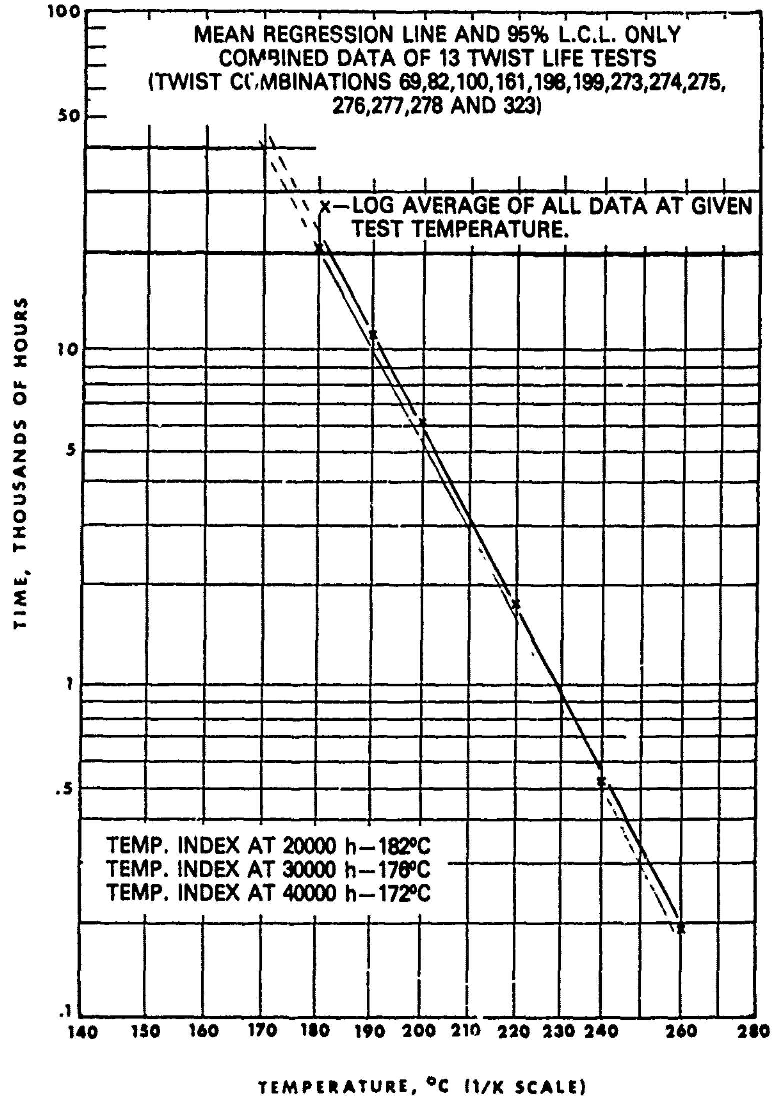


Fig. 12--Life-temperature characteristics from combined aging data for 13 twist combinations using polyester-overcoated magnet wire and Class 155 impregnating varnish

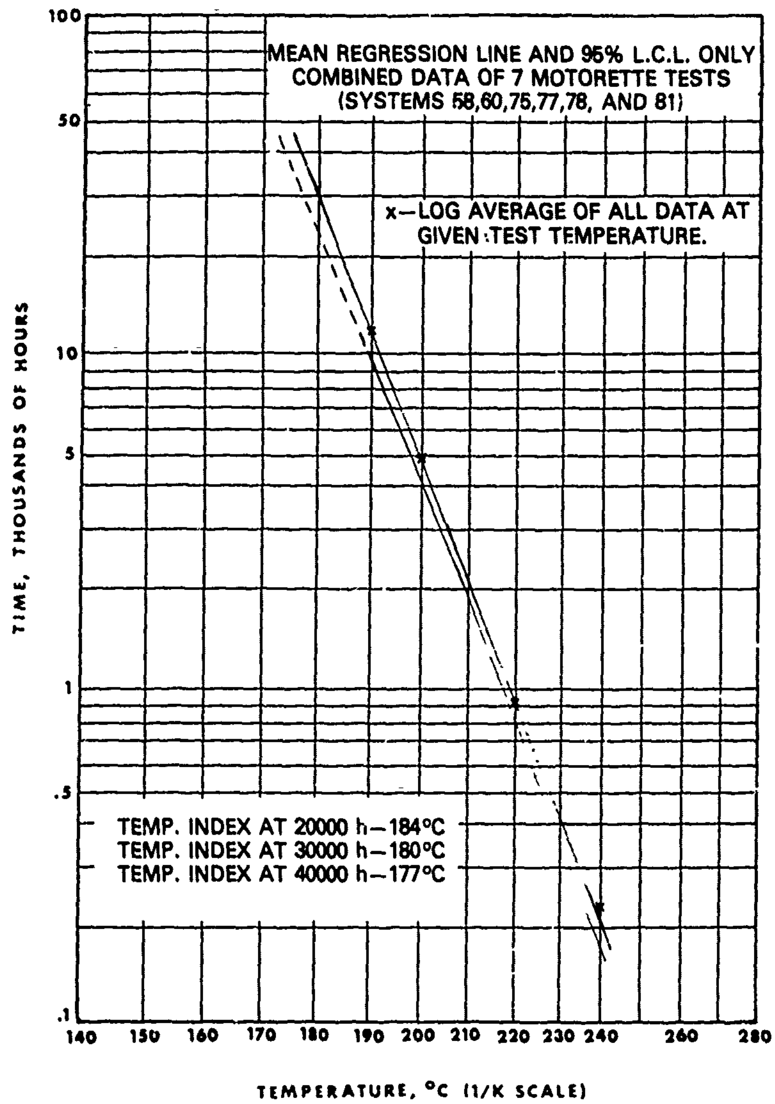


Fig. 13—Life-temperature characteristics from combined aging data for seven motorette systems using polyester-overcoated magnet wire and Class 155 impregnating varnish

When thermal aging tests are conducted on the same magnet wire unvarnished, the temperature index moves up from 180°C to 186°C at 20 000 h, as shown in Fig. 14. This higher rating for the unvarnished magnet wire reflects a thermal downgrading due to the varnish. Fortunately, this is offset by the mechanical bonding and the sealing out of contaminants, which often are critical factors. It has been found that certain higher temperature varnishes, such as the silicone-modified ones, do not downgrade the thermal life but instead upgrade it by as much as 12°C, as illustrated in Fig. 15 and 16. Unfortunately, these varnishes have a considerably lower bond strength characteristic, which renders them unsatisfactory for many applications.

When the newly established polyester magnet wire benchmark of 20 000 h is applied to the varnished polyvinyl formal magnet wire thermal aging data, it shifts the thermal index rating from 105°C (at 40 000 h) to 115°C (Figs. 17 and 18). The 105°C temperature index was more or less arbitrarily chosen for the polyvinyl formal before field experience dictated it. Therefore, the higher figure of 115°C may be an appropriate rating that would have been justified in the same manner as the 180°C rating for the polyester-overcoated magnet wire. In fact, there is now evidence that the 105°C polyvinyl formal rating may be a conservative figure. European motor manufacturers have been rating polyvinyl formal well above 105°C (at 120°C) for many years [8], and in this country the transformer industry [9] has done likewise.

THE NEED FOR THERMAL EVALUATION PROCEDURES

As a purchaser and user of insulating materials, the Navy naturally has a keen interest in both the development and the end use of functional test procedures. The Navy realized that proper development and use of these procedures would greatly benefit both industry and military.

The purpose of thermal endurance tests may be divided into two general categories, as follows:

1. To aid in selection and procurement of insulating materials for electrical equipment that will achieve maximum reliability at minimum cost

2. To provide engineering data that will ensure the fullest use of the potentials of these materials when used in combinations, as systems, in electrical equipment.

In reference to the first purpose, the Navy must use the best available means of screening insulating materials for military purchase and use. One of these means is temperature classification of materials based on thermal evaluation tests. Since there are existing materials that have been accepted for certain temperature classifications based on long-time field experience, the life-temperature characteristics of these materials determined by test provide a basis for comparison with the thermal life of new materials. The reason for assigning these materials to definite temperature classes is to provide this means of comparison and to designate each class by a single number for purposes of standardization. To accomplish this, the Navy must set concrete and definite limits based on careful consideration of the many factors involved.

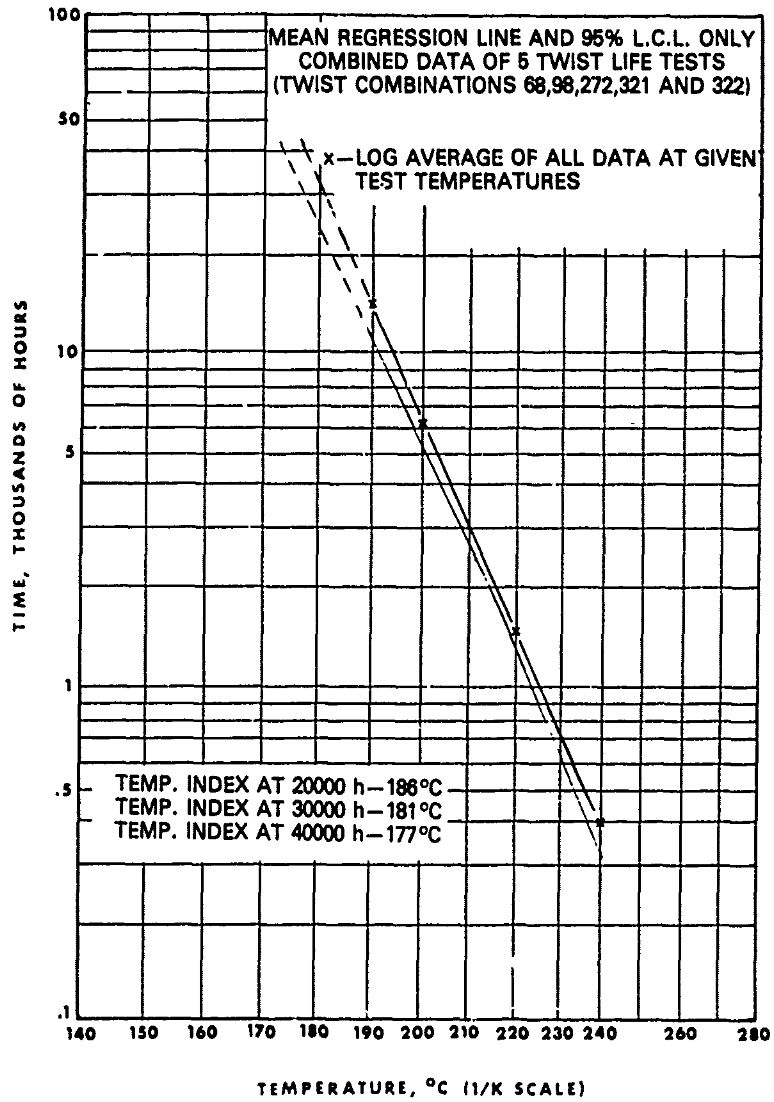


Fig. 14—Life-temperature characteristics from combined aging data for five unvarnished twist tests of polyester-overcoated magnet wire

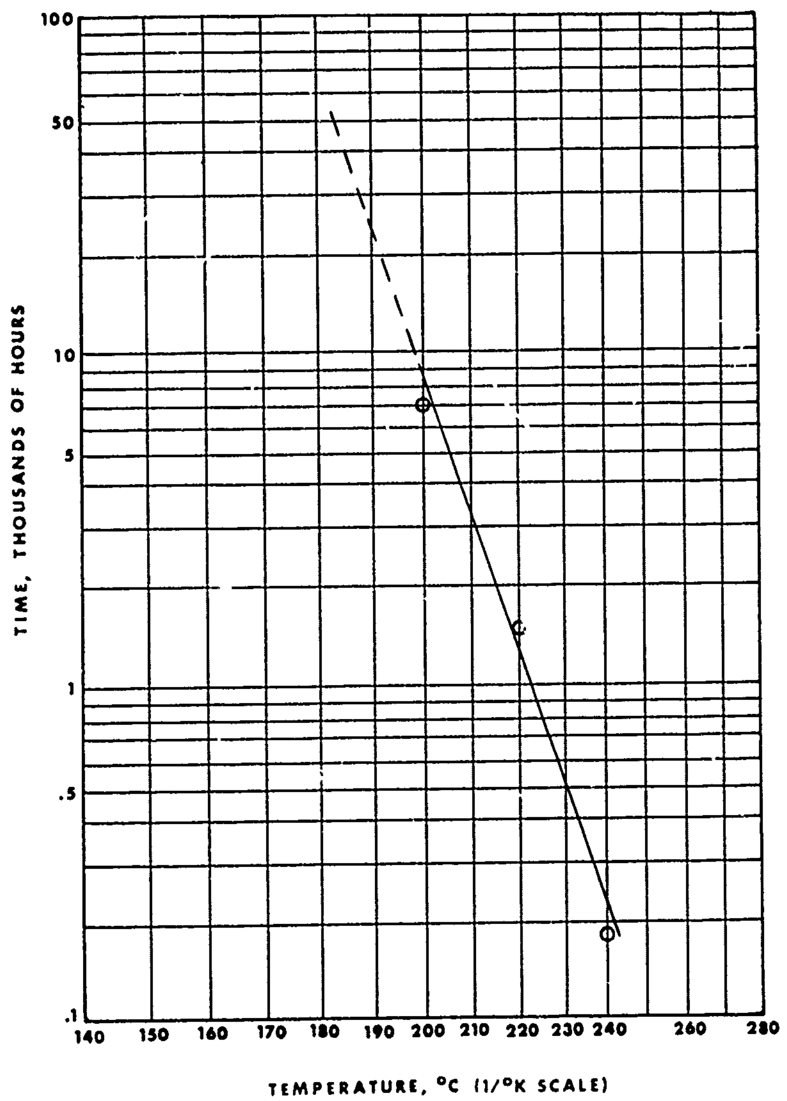


Fig. 15—Life-temperature regression line and log average lives for polyester-overcoated magnet wire twists varnished with modified silicone varnish (twist combination no. 70)

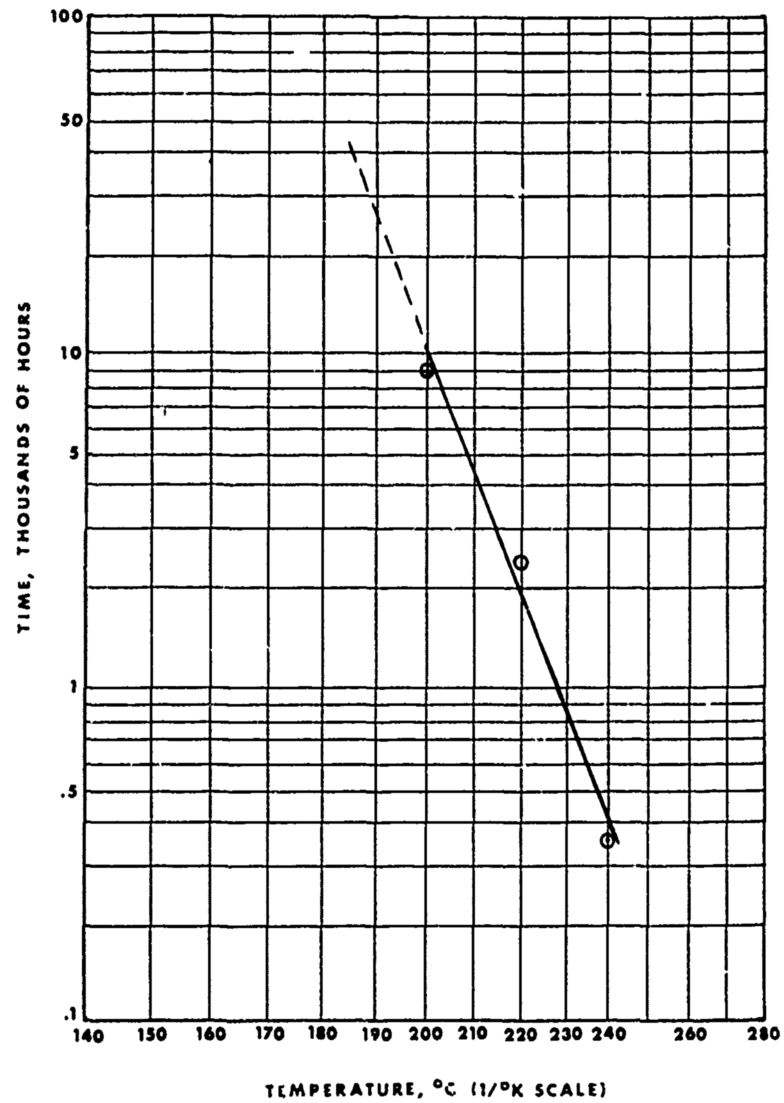


Fig. 16—Life-temperature regression line and log average lives for polyester-overcoated magnet wire twists varnished with modified silicone varnish (twist combination no. 99)

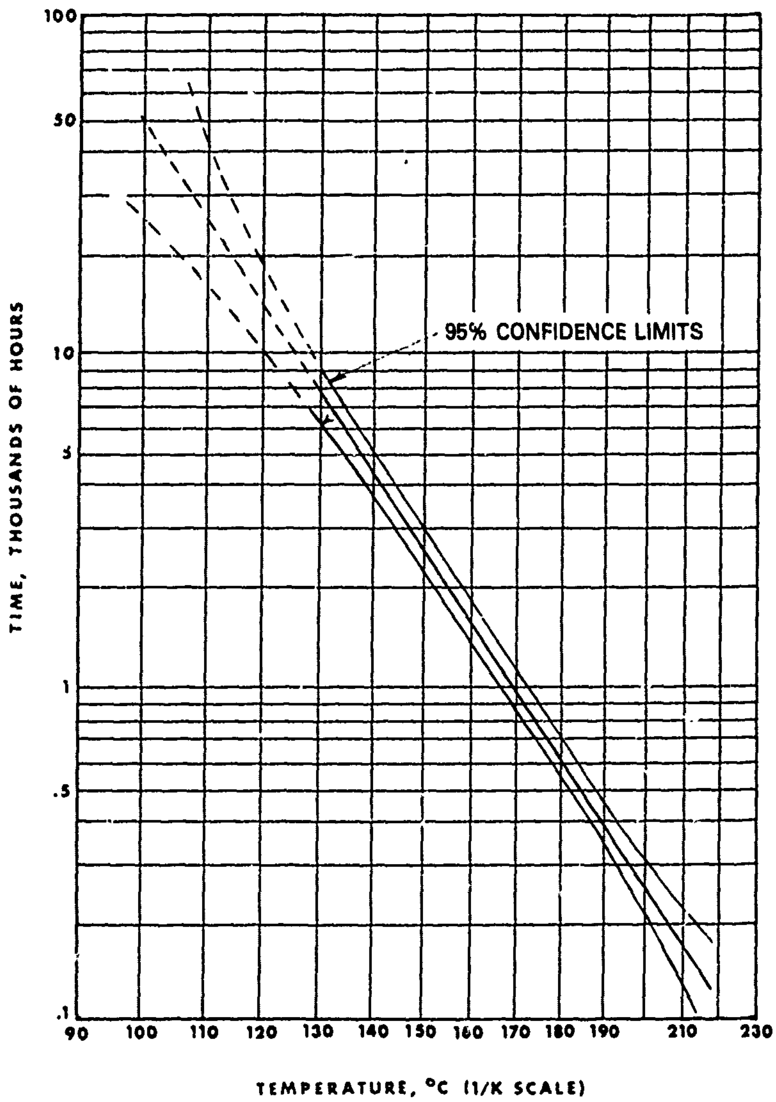


Fig. 17—Life-temperature regression line from combined data of five laboratories (total of 36 test points) for polyvinyl formal magnet wire twists varnished with phenolic alkyd varnish

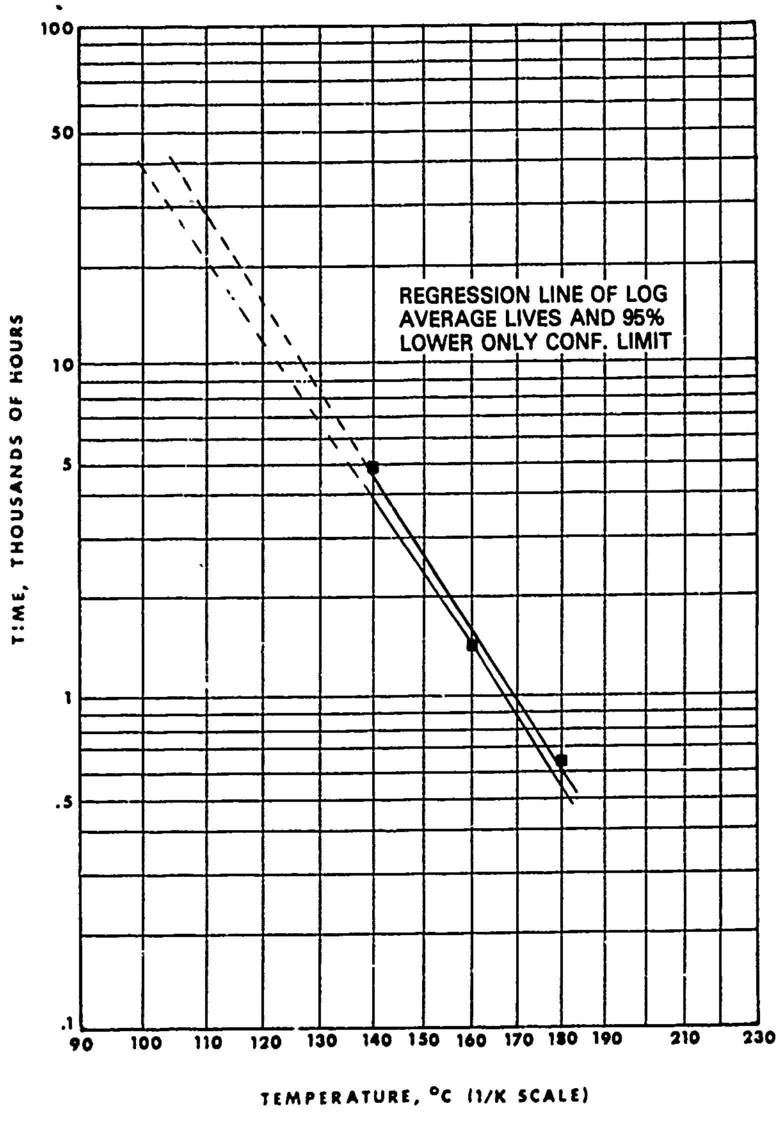


Fig. 18—Life-temperature characteristics of twist combination no. 135B, polyvinyl formal magnet wire with phenolic-type varnish

As for the second purpose of test procedures (to provide engineering data), the Navy recognizes that the thermal endurance characteristics of insulating materials may not correlate with the performance of those materials when combined in systems. This was recognized as much as 15 years ago, when an article was published reporting the thermal investigations of 13 insulating systems functionally evaluated by use of the motorette [10]. Following are quotations from this article:

1. "It has become apparent that the thermal stability of various components is influenced by the aging characteristics of the companion components of the system. The useful life of organic varnished glass phase material can be increased as much as 900% by the proper selection of the magnet wire."

2. "The interrelationship of the individual components and their influence on the first failures of a system is a critical factor in determining the aging characteristics of the system."

This important interrelationship was dramatically illustrated several years later during the IEEE 117 round robin test program, when a neoprene-treated tie cord was used in the fabrication of the motorette test specimens [11]. The incompatibility was a reaction between the neoprene and the polyvinyl formal magnet wire, causing erratic and premature wire failures to occur under the tie cord.

It is recognized that a wide variety of results can be obtained, depending on such factors as the test procedure followed, the faithfulness by which the procedure is carried out, and the various test conditions employed.

Thermal evaluation data can provide a good indication of minimum performance requirements, whether it be on materials for the purpose of screening and purchasing or on complete systems for gaining engineering design data for equipment specifications.

Military Specification MIL-E-917D (Navy), covering the basic requirements of electrical power equipment for naval shipboard use, explains clearly the differences between materials classification and systems classification. Paragraph 3.5.1.10, in particular, says that "a material that is classified as suitable for a given temperature may be found suitable for a different temperature, *either higher or lower*, by an insulation *system* test procedure." It is further pointed out in par. 3.5.2 that "experience has shown that the thermal life characteristics of composite insulation systems cannot be reliably inferred solely from information concerning component materials."

Navy experience has shown that materials testing of such components as film-coated magnet wire and impregnating varnishes provides a better basis for temperature classification than other supporting materials because the performance requirements are not too different in most applications. This was supported by the report on the 13 systems mentioned in Ref. 10. In fact, it was shown that where the phase and ground (slot) insulation supported the magnet wire (allowing the magnet wire to fail first), there was reasonably good correlation between the wire insulation life of the system and that obtained by the ASTM D2307 Twist Test. It should be pointed out here that the motorette procedure used was the Navy's version of the IEEE 117 procedure, employing a highly controlled humidity cycle using 100% relative humidity without visible condensation.

Because of the consistency of aging data that can be obtained by careful adherence to the ASTM D2307 procedure and the modified IEEE 117 procedure, it was determined that material classification by temperature classes was feasible for purchase specification purposes such as those outlined in the J-W-00117 specification [12]. It must be remembered, however, that this was done only after rigid rules on use and interpretation of the data were specified. For example, extrapolation is allowed only after realistic and appropriate requirements have been met in regard to linearity and other factors such as maximum and minimum average life data.

DEVELOPMENT OF EXPERIMENTAL EQUIPMENT

Magnet Wire Twist Test Procedure

During the early stages of development and use of the twisted pair magnet wire procedure (IEEE 57) the method required handling each individual specimen throughout the prescribed heat aging and voltage stressing cycles. Thus, for a temperature-life data experiment with four temperature points a minimum of 40 specimens presented a problem of handling and experimental processing.

Two variables (both mechanical) were unavoidably introduced by the individual handling of the specimens as they were removed from the container (which was in the form of a box, tray, or wire basket), placed on the voltage stressing apparatus, and later returned to the container. The first was possible damage due to the handling itself, and the second was adhesion damage experienced with some magnet wires when specimens were placed together or on top of each other in the containers. Adhesion of the wires was due to the plastic flow of the wire coating during the earlier stages of thermal aging. This resulted in actual rupture of the insulating film as the specimens were pulled apart at room temperature for voltage stressing.

As a solution to these problems the multiple twist specimen holder, shown in Fig. 19, was developed at NRL. The holding fixture permits mounting the specimens in fixed, permanent positions, thus protecting them from these damaging conditions. The assembly can be handled as one unit, eliminating the need of a container or tray. It offers other advantages as well. The open sides of the frame provide more adequate circulation of air than a box or similar container. Also, the time required to voltage stress the specimens is reduced to one-tenth of the conventional time required if the stressing is done with a multiple tester such as the one designed at NRL for use with the holder (see Fig. 20). A study conducted at the Naval Ships Research and Development Laboratory [13] comparing several variations of the NRL twist specimen holder shows little if any significant difference in the results obtained.

An additional contribution was made to the magnet wire twisted pair test procedure in the refinement of the original specimen forming jig. The NRL forming jig, illustrated in Fig. 21, allows for a more uniform and faster method of making twist specimens. It was discovered that the angle at which the wire was formed as it left the twisted portion of the specimen was a variable contributing to premature failure of the insulation. The use of the forming jig not only drastically reduces fabrication time but also almost entirely eliminates handling of the specimen during the process.

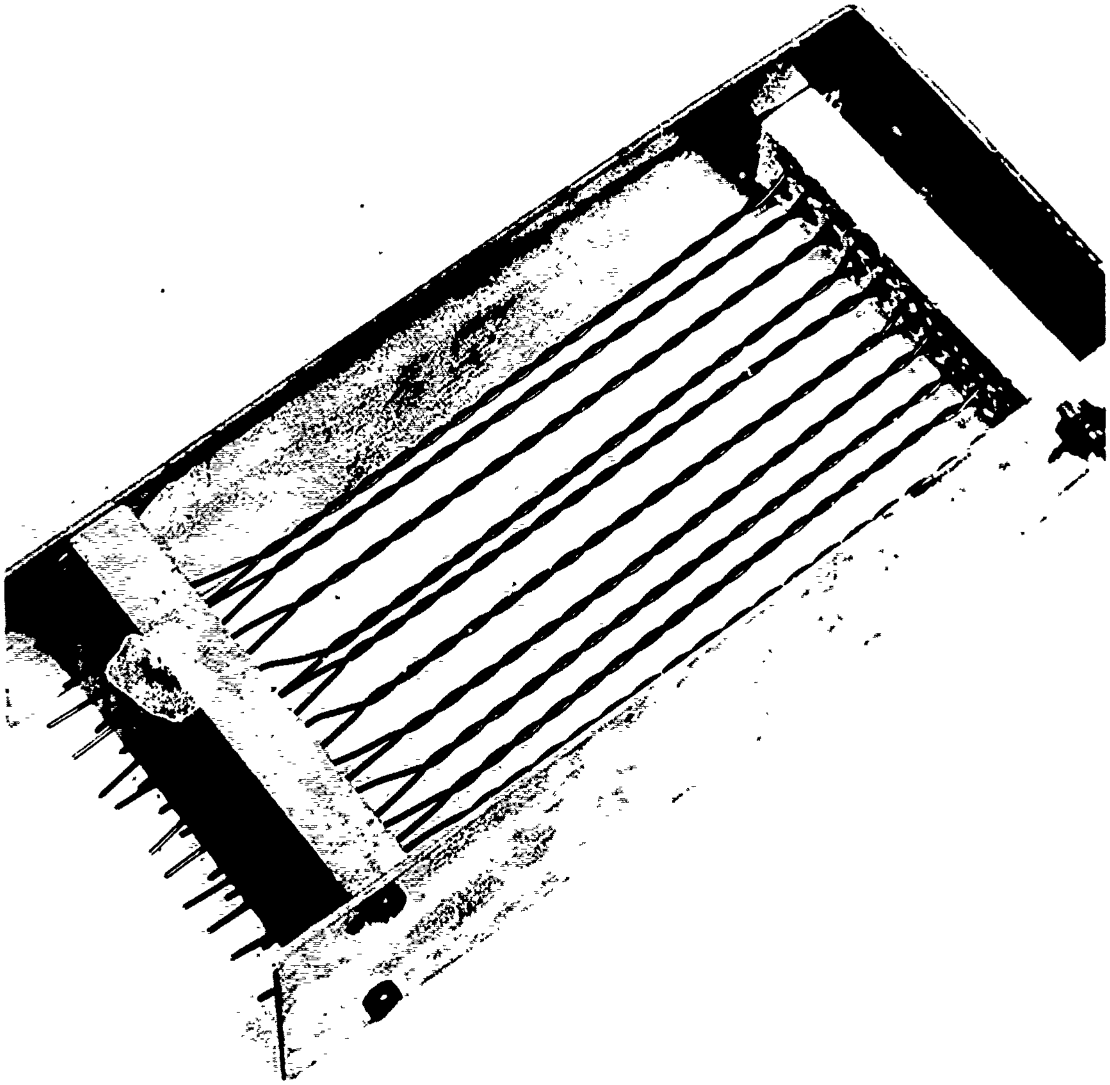


Fig. 19—NRL multiple-twist-specimen holder

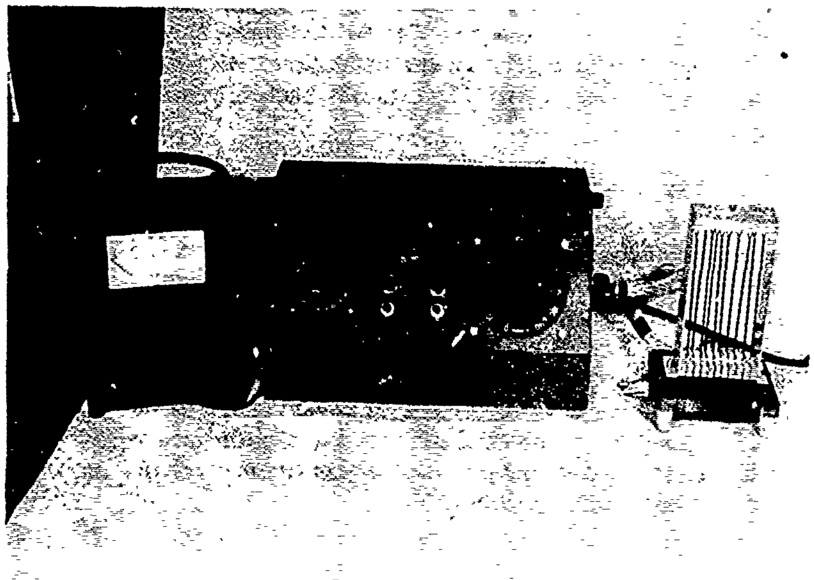


Fig. 20—NRL multiple-twist specimen voltage-stress tester

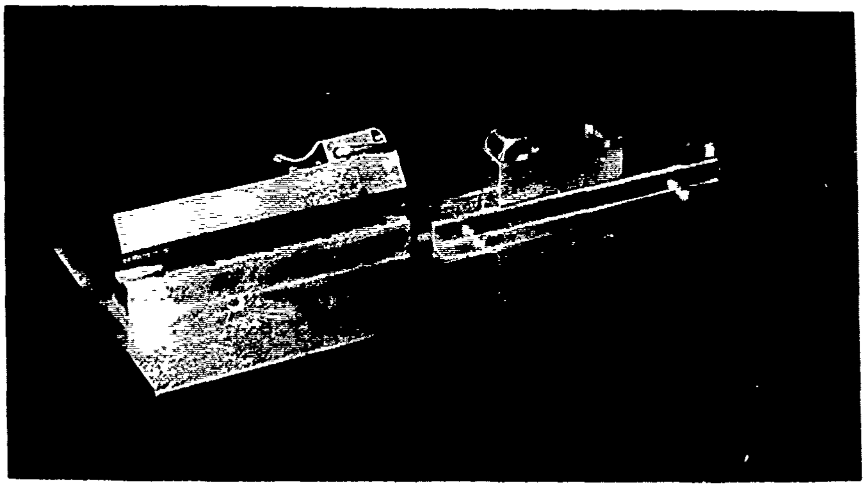


Fig. 21—NRL twist specimen forming jig

One major limitation to the magnet wire twisted pair test procedure was the original twist-forming apparatus, which worked satisfactorily only with film-coated wire. When attempting to make fibrous-covered magnet wire twisted pairs, the rough covering of the two adjacent wires would bind and rupture the insulation. Because of this problem thermal aging of fibrous-covered magnet wire has not been required by government and industry specifications.

The solution to this problem was to design a special universal twist-making device for use with fibrous as well as film-insulated wire (Fig. 22). In use of this device, a loop of wire is suspended vertically with individual weights attached at the two free ends, guided by two plastic pulleys. Unlike the original device the weights rotate freely, allowing twists to be formed without any grabbing or binding of the wire.

Thermal aging tests were conducted on film-insulated magnet wire twisted pairs made using both the original and the new type of device to compare the resulting aging data. The tests indicated that the thermal life was the same regardless of which device was used. Thus, it was concluded that the device was suitable for making twisted pairs from either type of insulated magnet wire.

Motorette Test Procedures

Although the IEEE 57 (later adopted by ASTM as D2307) magnet wire test procedure proved to be a significant contribution to screening and classifying magnet wire according to temperature classes, it is limited inasmuch as it is no more than a materials or component evaluation. Except for magnet wire-varnish combinations, it does not take into consideration the interrelationship of other materials and the functional life reflected in a complete insulation system. The IEEE 117 motorette procedure [14] was developed to meet the need for a more functional systems evaluation procedure. The motorette models the elements of a randomly wound motor. Its components consist of two bifilar wound magnet wire coils so that conductor-to-conductor electrical tests can be made. The two coils are inserted in a slot section and are insulated from each other by sheet phase material and from the motorette frame by slot liners. Slot wedges are placed in the slot, compressing the coils together to reduce coil motion. Details of parts and assembly may be found in the IEEE 117 Test Procedure. Because of the unavoidably complex nature of the motorette procedure, it involved many more variables and consequently presented many experimental problems that had to be solved before it could be considered reliable and useful.

Standardization

After the original round robin motorette test program was conducted to check correlation between laboratories using the IEEE 117 Test Procedure, it became apparent that the test results were not very closely in agreement. The reasons for poor correlation were difficult to determine because there was no certainty as to the identity of materials used or the degree of faithfulness to the procedure. Yet it was necessary to determine the limitations of the procedure's accuracy if the relatively high cost of the procedure was to be justified. The Naval Research Laboratory contributed to the investigation of the variables by conducting an analysis of the motorette specimens used by each

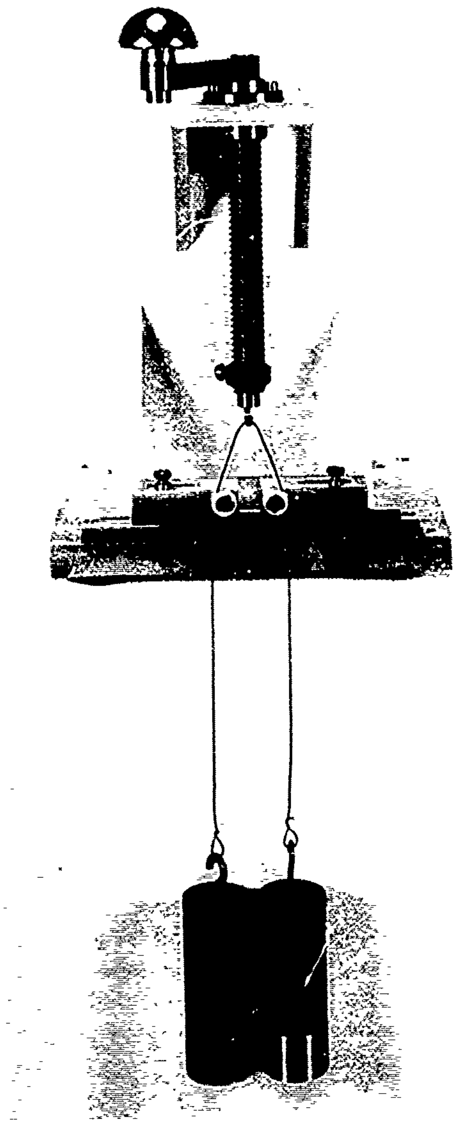


Fig. 22—NRL universal twist making device

laboratory in the round robin [15]. One motorette from each of the nine participating laboratories was obtained for thorough examination, to determine significant differences as well as any fundamentally poor construction that might contribute to the lack of correlation.

The nine motorette specimens examined are illustrated in Fig. 23. Figures 24, 25, and 26 show an enlarged cross section of the slot portion of each motorette. The small motorettes "D" and "E" were submitted by laboratories that did not participate in the round robin. Due to a move of its laboratory and a change in its activities, one participant in the motorette tests was unable to submit a sample. It is to be noted that these samples were submitted 2 years after the round robin tests began; and in some cases the motorette was manufactured from whatever materials were on hand and most closely simulated the original specified components. Because of this, one should place more emphasis on the placing of materials and other structural details than on the particular materials employed. Some of the more significant variations included:

Wire:	14 to 19 turns; loose to very tight pack in slot.
Varnish:	0.05-0.25 mm (0.002-0.010 in.) build; very light to very dark; poor to very good penetration into slot.
Phase:	Very loose to tight fit to slot liner; some "folded in," others "notched" to fit slot.
Slot liner:	0- to 9.5-mm (0-3/8 in.) protrusion from slot.
Sleeving:	None, organic varnished glass, silicone varnished glass, vinyl over glass; some sleeving placed in slot.

From the results of the analysis, it was concluded that significant assembly and manufacturing differences do exist and may contribute to poor correlation among laboratories.

Although the motorette was designed for functional evaluation, it must be kept in mind that it is subjected to far more severe environmental conditions in an accelerated test program than an equivalent motor insulation system would ever experience in normal use. Hence, even small deviations in construction or departures from standard procedures are amplified in their effects. Personnel directly associated with the manufacture of the motorettes must be aware of the more precise techniques required as compared with those of the usual production line product.

For a number of years the Navy has conducted a continuing research program, sponsored by the Navy Ships Engineering Center, on the various parameters influencing the thermal aging properties of electrical insulation systems. As the ramifications of this study were so numerous, NRL invited the Naval Ships Research and Development Laboratory (NSRDL) to share in the research work. In the interest of maintaining uniform accuracy in the joint experimental work, it was decided that a series of comparison studies would be conducted to determine the degree of correlation between two sets of life-temperature data, obtained at NRL and NSRDL, on a Navy standard insulation system.

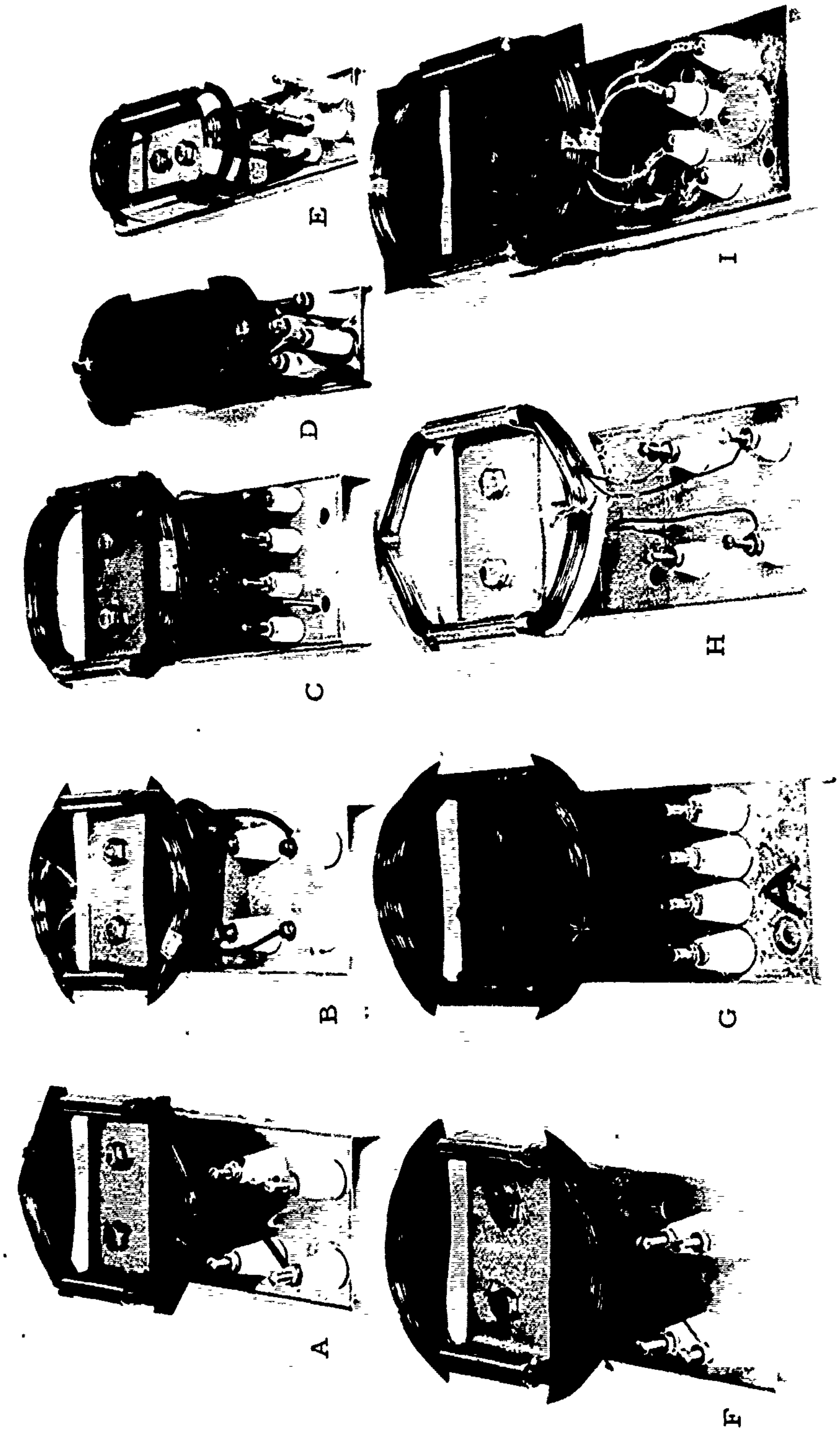
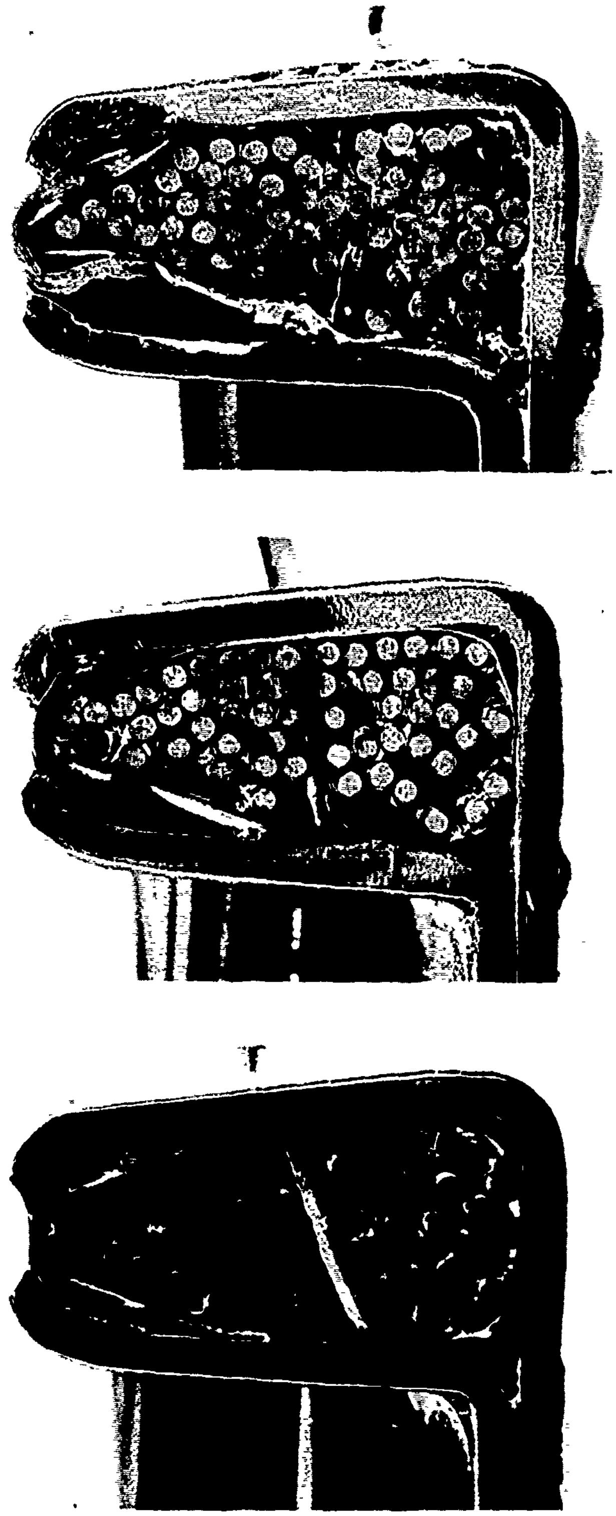
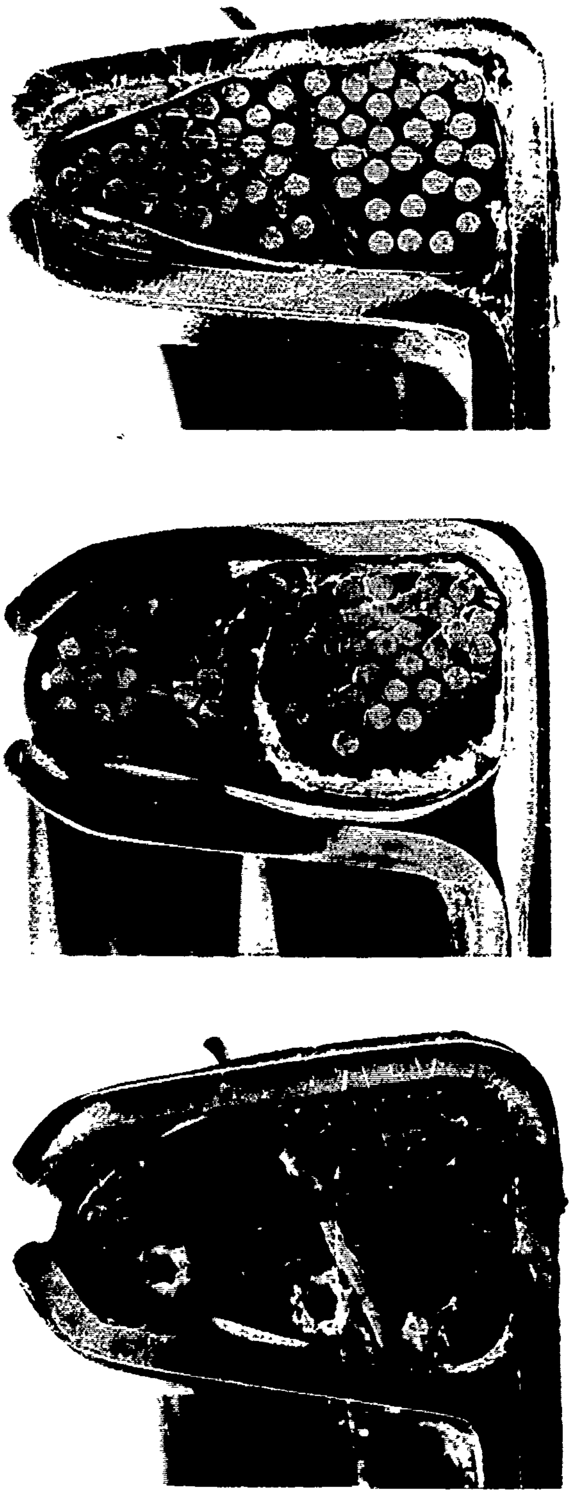


Fig. 23—Motorette specimens submitted by nine participating laboratories



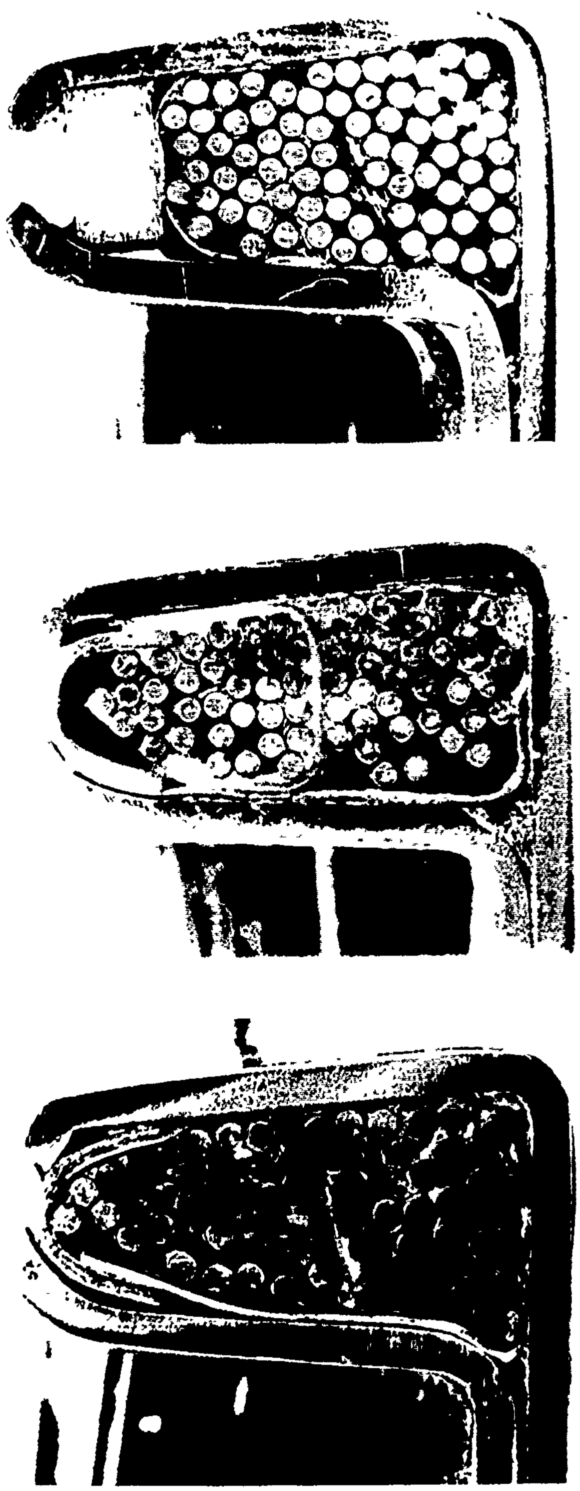
A B C

Fig. 24—Slot cross-section views of motorette specimens submitted by laboratories A, B, C



D E F

Fig. 25—Slot cross-section views of motorette specimens submitted by laboratories D, E, and F



G H I

Fig. 26—Slot cross-section views of motorette specimens submitted by laboratories G, H, and I

A typical Navy Class 105 insulation system was used for the motorette specimens. The system consisted of polyvinyl formal magnet wire; organic varnished glass phase; and organic varnished mica-glass ground materials. The system was impregnated with an oil-modified phenolic varnish. Identical materials were used by the two laboratories, and each fabricated its own specimens. The IEEE 117 Test Procedure was followed except for modification in the moisture cycle. The Navy version of the procedure used 100% relative humidity with no visible condensation in place of the 100% relative humidity with visible condensation called for in the IEEE 117 procedure. It had been determined several years earlier that no practical method was available that assured uniform and consistent visible condensation. (The Navy was currently developing a humidity cabinet in an attempt to solve this problem.)

Both laboratories, cognizant of the susceptibility of errors due to the many variables, established stringent control over the parameters. The significance of this control is evident in the high degree of data correlation between the two laboratories. The NRL data are plotted in Fig. 27, and the NSRDL data in Fig. 28.

Humidity Conditioning Cycle

During development of the motorette procedure the Working Group concentrated on one main endeavor, which was to seek out and correct various factors influencing the test results. Probably the most critical factor with respect to both reproducibility within one laboratory and correlation between laboratories is the humidity conditioning cycle. The IEEE 117 procedure stipulates that "each specimen is to be exposed for at least 48 hours to an atmosphere of 100% relative humidity with visible condensation on the winding." Experience has shown that to maintain this condition consistently throughout the conventional "plus-dew" chamber is extremely difficult. An exchange of experiences among various laboratories revealed that due to such factors as loading, chamber design, and room ambient variations there has been a wide variance in humidity conditions, ranging from heavy condensation to no visible condensation on some specimens.

In an attempt to find a practical solution to this problem, the IEEE 117 Working Group asked the Navy to devise a chamber that would meet the following requirements:

1. Provide a uniform and consistent visible condenstaion throughout the test area of the chamber

2. Perform independently of room ambient fluctuations

3. Be completely self-contained so as to not require external plumbing or wiring

4. Accommodate up to 60 motorette specimens at one time

5. Be capable of passing through a standard 30-in. (0.75 m) door

6. Be reasonable in cost.

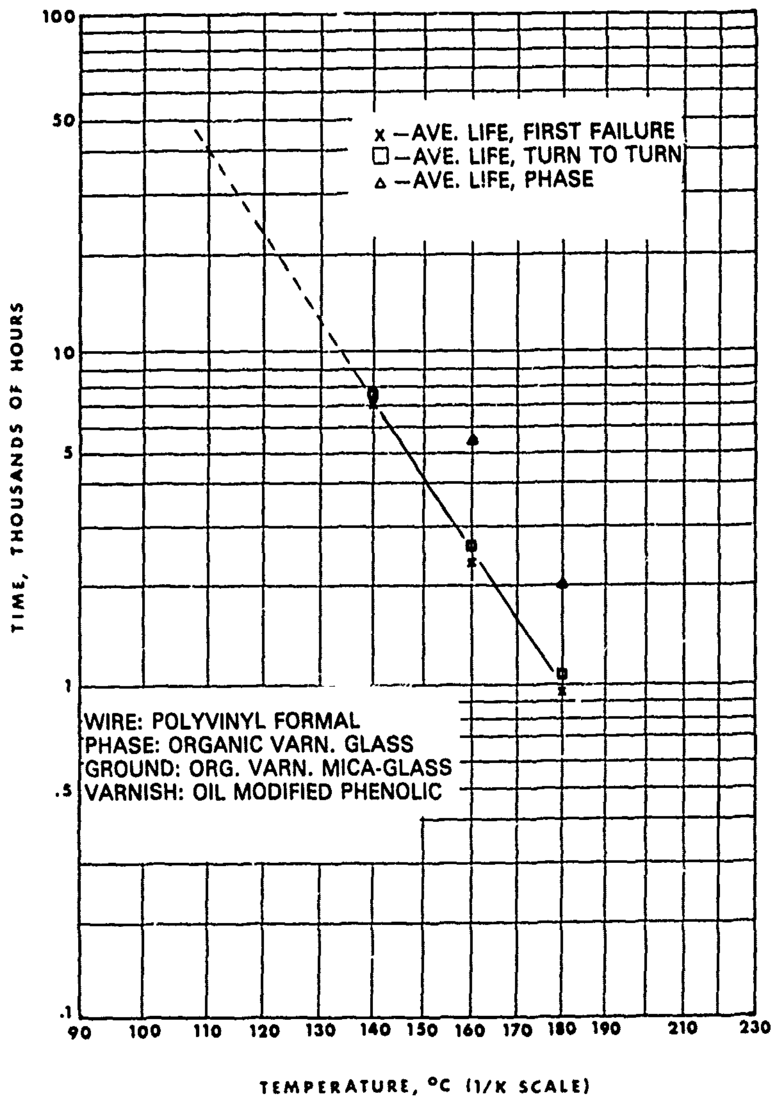


Fig. 27—Life-temperature regression line of log average lives of motorette system G tested at NRL

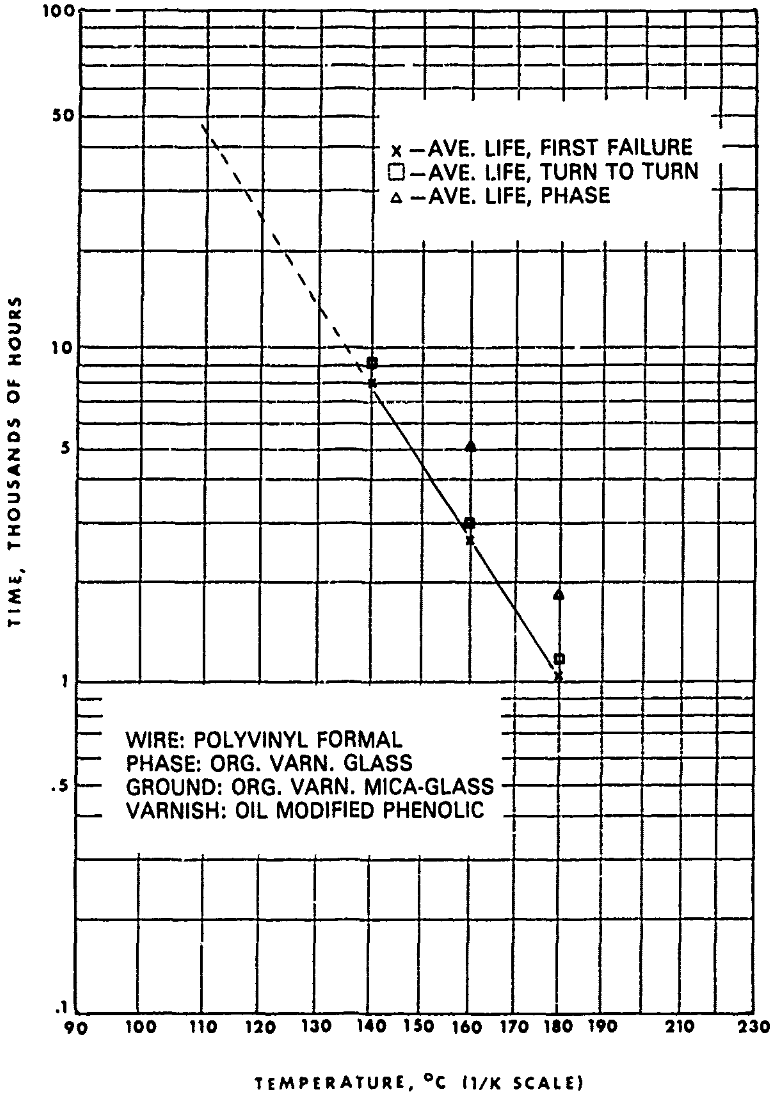


Fig. 28—Life-temperature regression line of log average lives of motorette system G tested at NSRDL

Figure 29 is an artist's cutaway view of the chamber interior, illustrating the water bath, cooling rack, specimen drawers, and mounted specimens. The NRL pilot model illustrated in Fig. 30 when assembled is 42 in. wide, 62 in. long, and 52 in. high (1.07 x 1.57 x 1.32 m). The chamber proper is 20 in. high and is mounted on a rack that accommodates the heat exchanger, coolant reserve tank, and circulating pump. The double-walled cover is the only chamber outer surface that is insulated and is heated slightly (and thermostatically controlled) to prevent condensation and resulting dripping of water on the specimens.

Figure 31 shows the basic principle employed. The specimen rack is refrigerated by a circulating coolant (water) that is thermostatically controlled to maintain a specified temperature differential between the specimens and the surrounding chamber air. This differential is independent of normal room ambient variations. Since both the heated water bath and the coolant are thermostatically controlled, this independence is limited only by the capacity of the system. Temperature control is not lost in the event that the room ambient should rise to a temperature above that of the water bath. The heat lost to the refrigerated rack keeps the water within the control of the heater, allowing the balance of temperatures to be maintained. In case the room temperature falls below that of the cooling rack, control is preserved by the heat supply of the water bath heater. This balancing effect between heating and cooling systems eliminates the need for the chamber to be in a temperature-controlled room, as a conventional dew-plus chamber must be. The interior of the chamber was so designed that all motorette specimens would be the same distance above the water bath and below the roof of the chamber, so that specimens would be equally influenced by such factors as radiating surfaces, air temperature, and relative humidity. Figure 32 illustrates a specimen drawer and a set of 10 motorettes mounted on an open rack. The mounting rack greatly facilitates handling of the specimens during the humidity, heat aging, and vibration cycles.

Figure 33 shows the rack of motorette specimens placed in the drawer with the four-pronged quick-disconnect plugs in place. After the desired exposure to moisture, the specimens are connected to a test stand by cables that lead to the receptacles on the faces of the chamber drawers. A typical setup for this purpose is shown in Fig. 34. The stand illustrated uses an improved NRL-designed test circuit that allows all components of 10 motorettes to be stressed simultaneously.

After the research and development on the condensation chamber was completed and a commercial model made available, the Working Group embarked on a second round robin motorette test program [11]. Figure 35 compares the combined life-temperature regression analysis curves for the 1958 original round robin and the 1968 reevaluation round robin. It can be seen that the second round robin data yield a 15°C higher temperature index at 20 000 h than the original data.

In reporting on the second round robin, the Working Group stated "that it *is* possible to obtain interlaboratory reproducibility with the proposed IEEE 117 Procedure." In spite of the refinements and established controls, however, the test procedure in two of the six laboratories varied enough that the results were considered outside the "test family." Because of this the Working Group cautioned that "inter-laboratory tests must insist on rigid adherence to test methods in all details if uniform results are to be achieved."

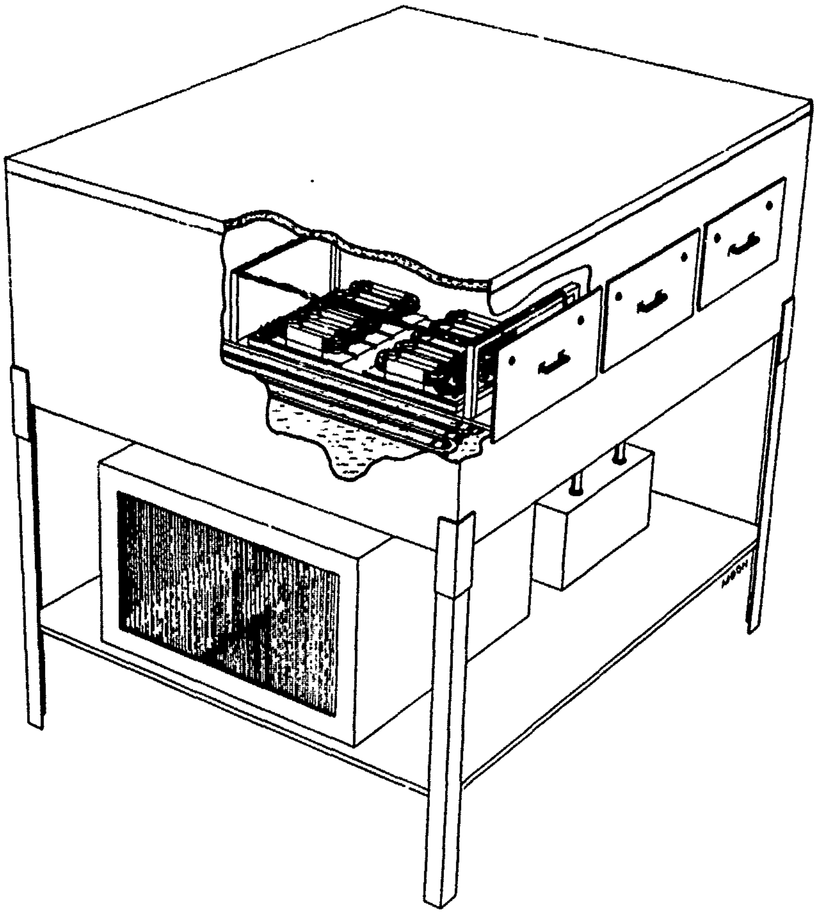


Fig. 29—Artist's cutaway view of condensation chamber

A further detailed study of the operating characteristics of the condensation chamber was then conducted by the Navy. A time-dependent ratio of surface to bulk absorption, which varied with the degree of thermal aging, was discovered. This phenomenon is illustrated in Fig. 36, which compares the insulation resistance of a new motorette with that of an aged one. Thus, caution should be exercised in adhering to the operating condensation chamber operating specifications recommended in NRL Report 7469 [16]. As a result of this study, a minimum exposure time of 48 h was recommended, with the difference in temperature between the motorettes and the air 25.5 mm (1 in.) above maintained at 1°C.

A round robin test was then conducted between NRL and NSRDL to investigate the degree of correlation that can be expected between two separate laboratories using the condensation chamber as a moisture conditioning method. To eliminate variables other than those contributed by the moisture conditioning cycle, both sets of motorettes were fabricated and thermally aged at NSRDL. One set was transported to NRL after each

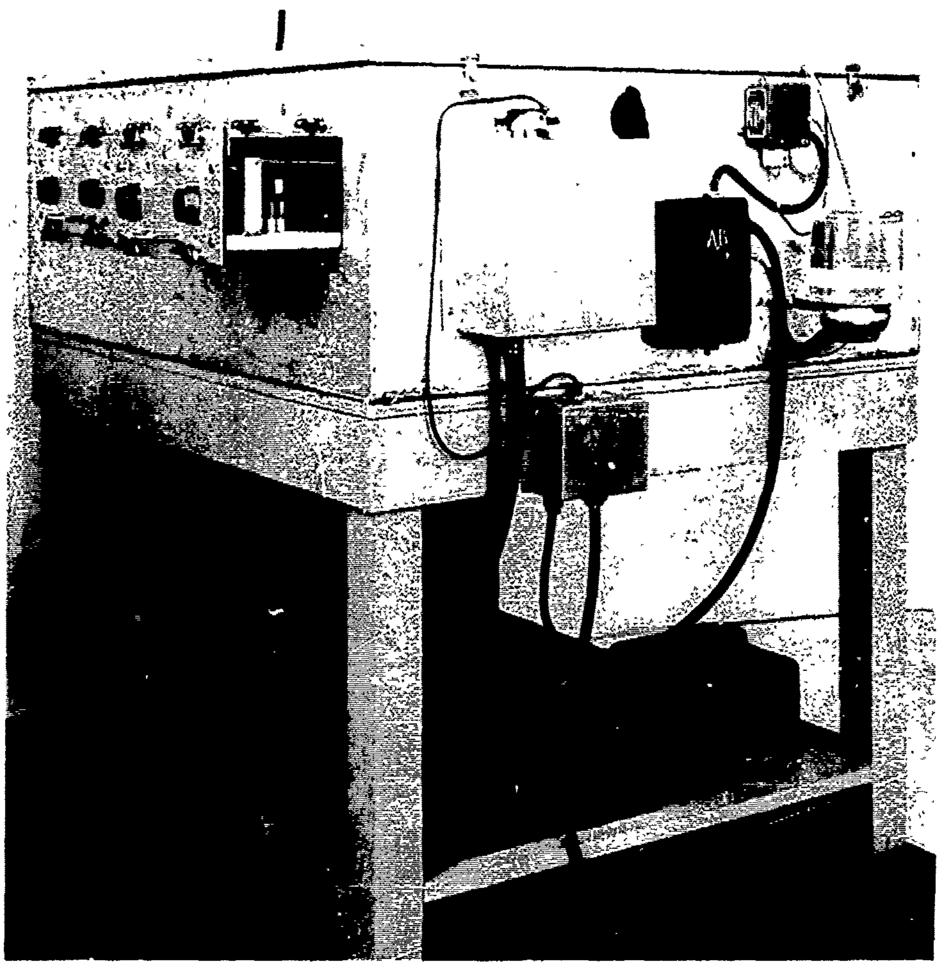


Fig. 30—Pilot model of NRL condensation chamber

aging cycle, to be exposed to vibration, humidity, and voltage stress cycles. The results demonstrate that good correlation can be obtained between laboratories if the condensation chamber is used under rigidly controlled conditions. Details of the test conditions and a breakdown of the data analysis are presented in Table 1. Plots of the regression lines, log average lives, and 95% confidence limits are given in Figs. 37 and 38.

The main advantage of the condensation chamber with its controlled visible condensation is the approximately 2:1 savings in testing time for a given test temperature as compared to the Navy's method of no visible condensation. This advantage allows one to test 10°C to 15°C closer to the assigned classifying temperature of the insulation system for the same test duration. For example, if when meeting the requirement that the lowest test temperature be no more than 20°C above the classifying temperature, the Navy method produces an average life of 10 000 h. The condensation chamber method would require only 5000 hours average life. In many circumstances, particularly in private industry, this 50% saving in testing time can be most important.

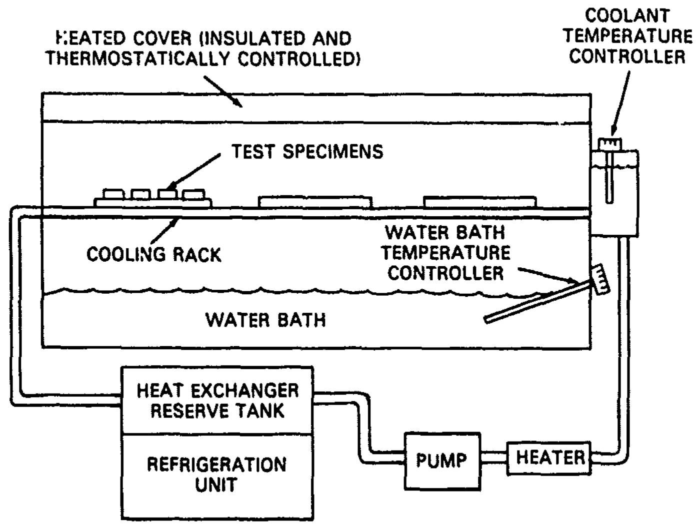


Fig. 31—Block diagram illustrating basic principle of condensation chamber

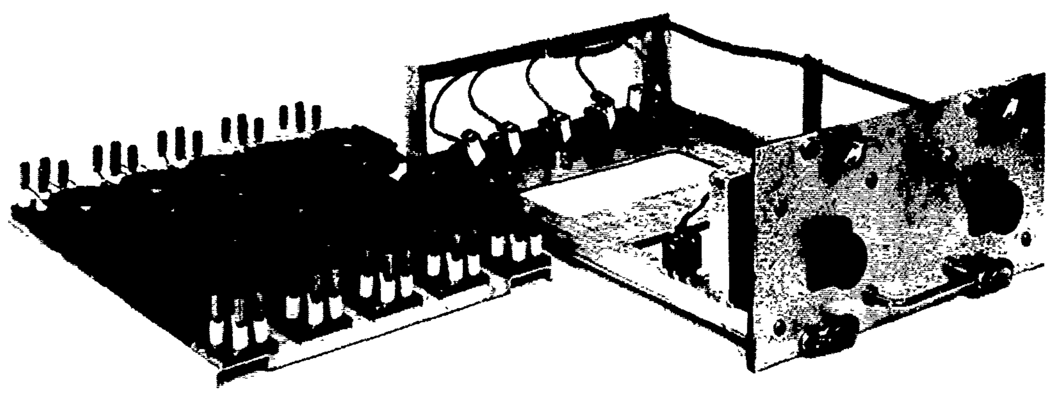


Fig. 32—Specimen drawer and set of 10 motorette specimens mounted on open rack

Since the Navy has already produced the great bulk of its motorette data over the past 20 years using the no visible condensation condition, and equipment designed for this method, it does not plan to make this major change at this time. However, the Navy does plan to consider using the condensation chamber in the future as more background experience and data are acquired on the newer, higher temperature insulation systems.

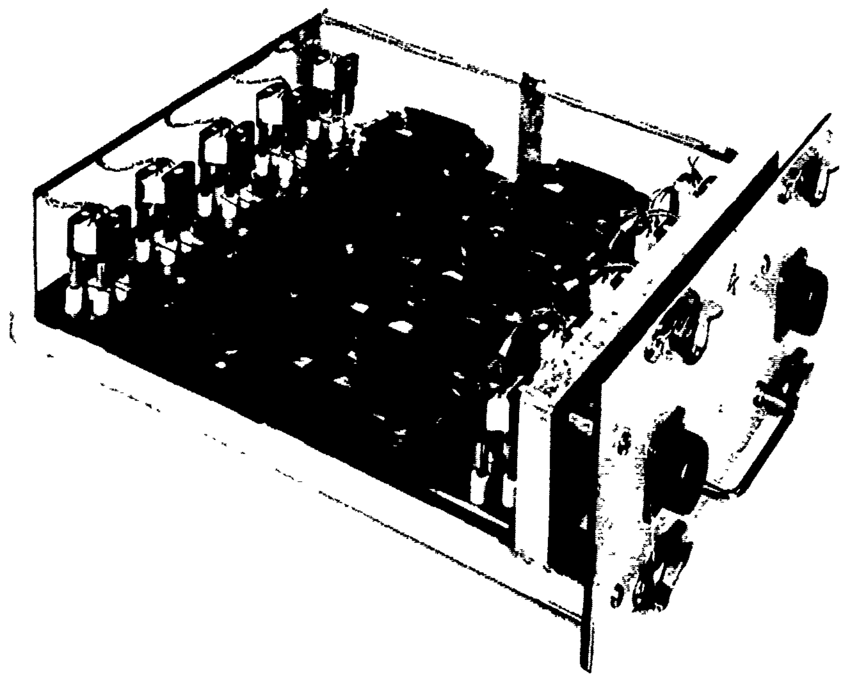


Fig. 33—Rack of motorette specimens in specimen drawer, with quick-disconnect plugs in place

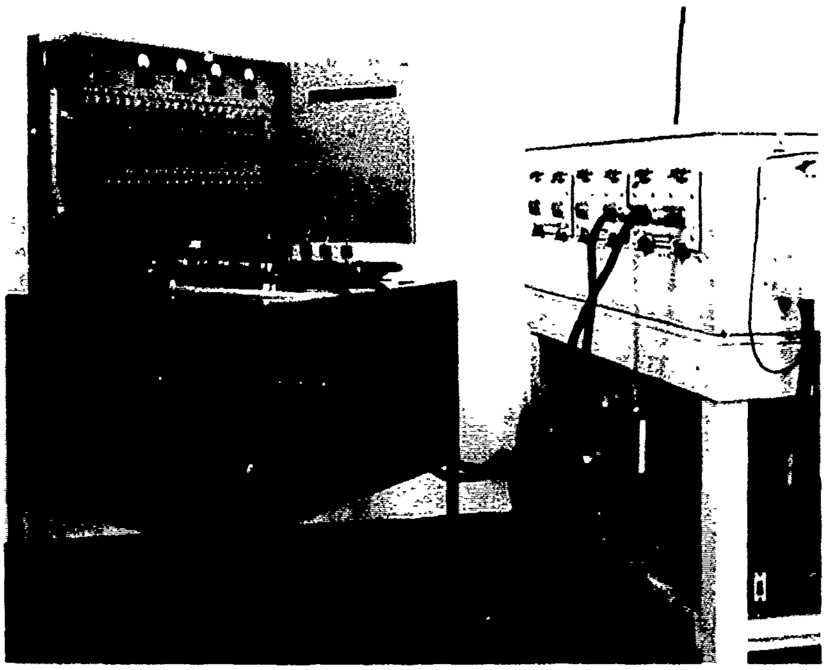


Fig. 34—Test stand and cables used with condensation chamber for voltage stress of motorettes

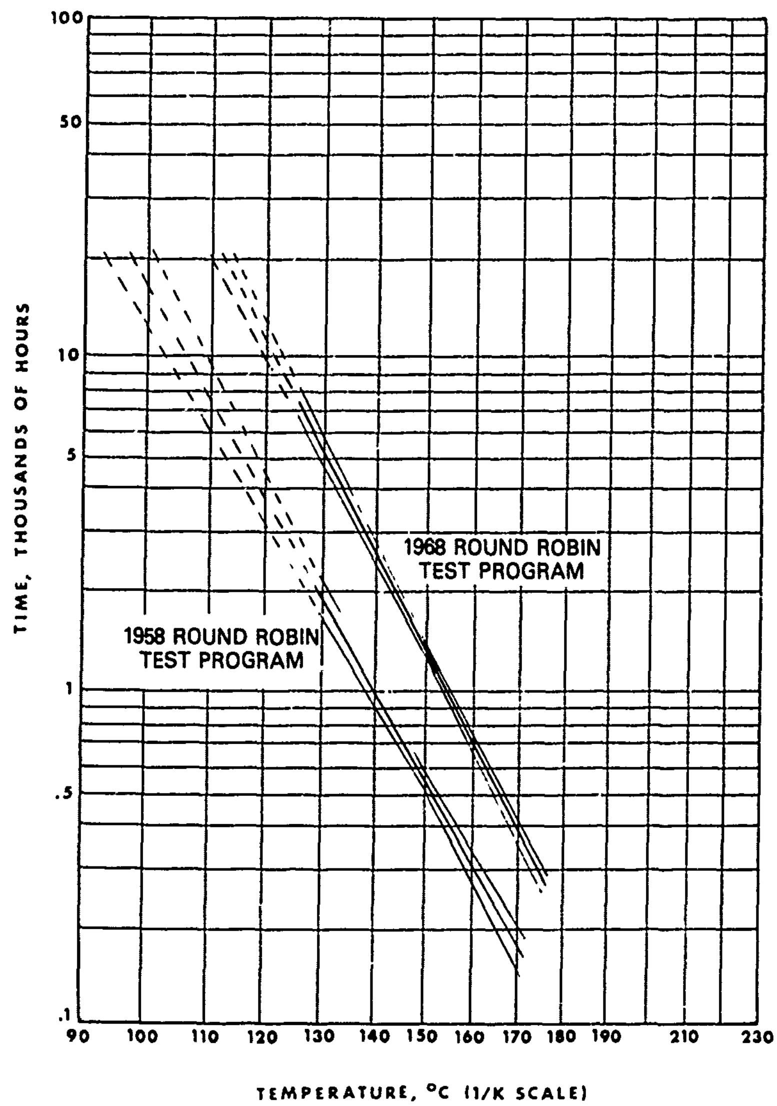


Fig. 35—Comparison of combined life-temperature lines and 95% confidence limits from 1958 and 1968 motoıette round robin tests

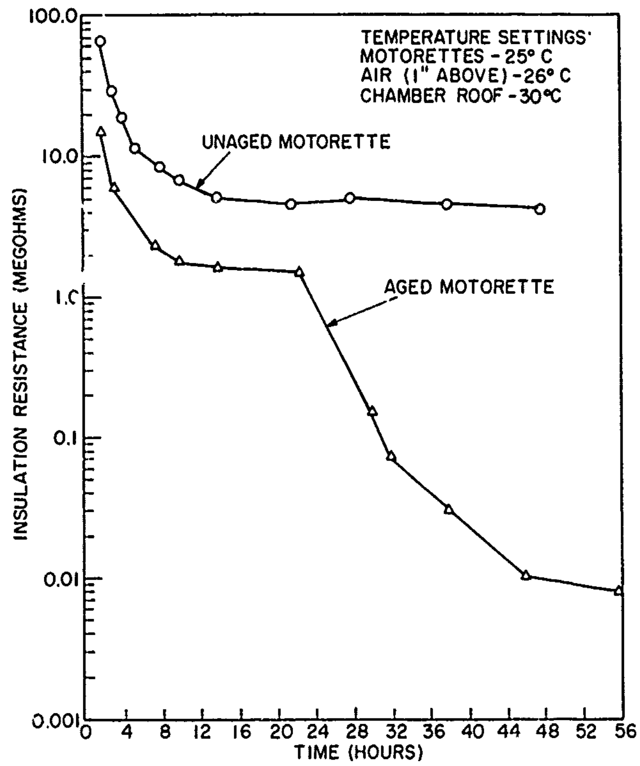


Fig. 36—Effect of moisture conditioning on the resistance of the winding-to-ground insulation in an aged and an unaged motorette

Table 1—First Failure Data*

Parameter	180°C		160°C		140°C	
	NRL	MEL†	NRL	MEL	NRL	MEL
Mean life (h)	169	175	569	569	2169	2074
Upper confidence limit	178	185	570	570	2290	2194
Lower confidence limit	160	165	568	568	2045	1958
Log average life	171	174	555	577	2181	2050
Arithmetic average life	174	176	558	585	2150	2054
Percent of standard deviation	17.0	15.2	11.6	15.9	9.5	7.4
Average standard deviation of all Components	15.2	17.0	16.1	16.8	10.9	10.2
Average number of cycles to failure	8.7	8.8	8.6	9.0	11.2	10.7
Types of first	4	2	5	4	7	5‡ T-T Top
failures and	5	4	6	7	8	6 T-T Bottom
number of each	2	4	0	0	4	2 Phase
type	4	7	2	0	6	3 Ground

*The humidity cycle was 64 h; minimum drying time, 7 h. Heat aging cycles were 20, 65, and 192 h, with corresponding aging temperatures of 180, 160, and 140°C.
†Marine Engineering Laboratory, now NSRDL.
‡T-T means turn-to-turn.

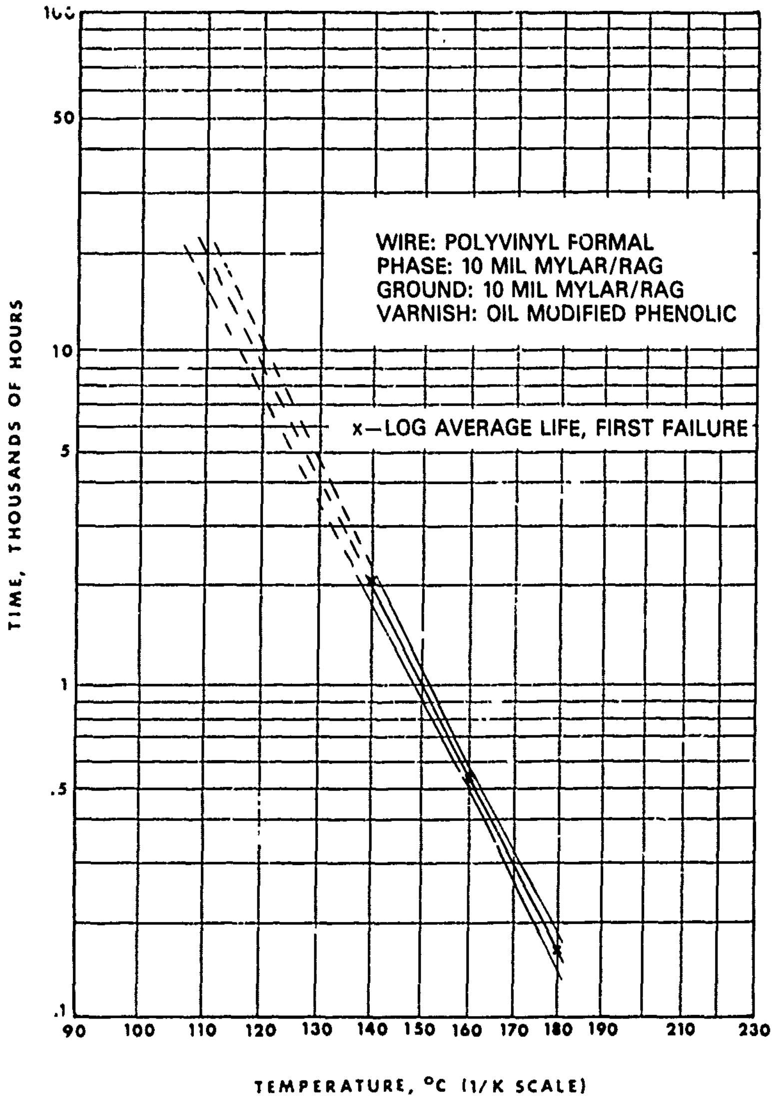


Fig. 37—Life-temperature regression line and 95% confidence limits of motorette system RR2, tested in NRL condensation chamber

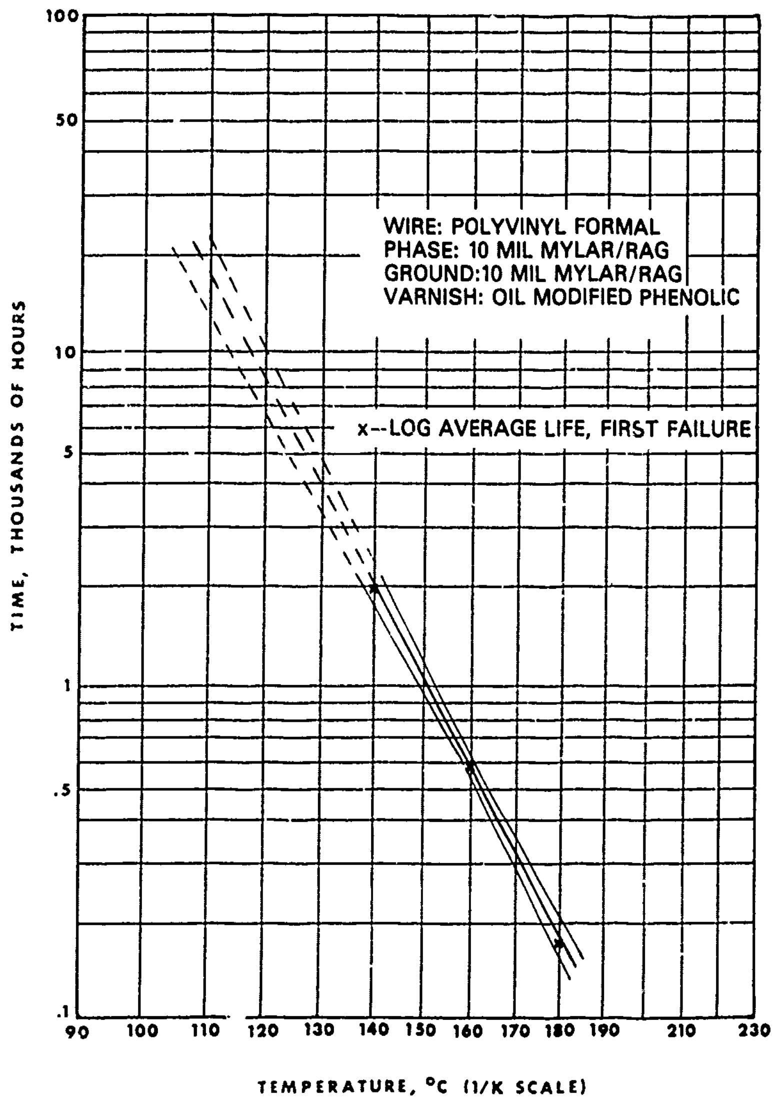


Fig. 38--Life-temperature regression line and 95% confidence limits of motorette system RR2, tested in NSRDL condensation chamber

TREATMENT OF DATA

Calculation for Placing Regression Line

A complete method for calculating the mean regression life-line, confidence limits, regression line comparisons, and other statistical observations for thermal life data is found in IEEE Standard 101-1972 [17]. However, for convenience the following method of calculating the regression line alone can be used when confidence limits and other auxiliary information are not required. It is outlined in IEEE Standard 101A-1974, which is an appendix to Ref. 17.

When the method of least squares is used, constant a and slope b of the regression line may be derived by the following equations:

$$a = \frac{\Sigma Y - b\,\Sigma x}{N} \tag{1}$$

$$b = \frac{N\,\Sigma XY - \Sigma X\,\Sigma Y}{N\,\Sigma X^2 - (\Sigma X)^2} \tag{2}$$

where

X = reciprocal of the temperature, in kelvins

N = number of end-point values (hours of life) used in the calculation

Y = logarithm of the hours of life at a given temperature.

When this is solved for constant a and slope b of the regression line, temperature t (in degrees Celsius) can be calculated by

$$t = \frac{b}{Y - a} - 273. \tag{3}$$

For convenience, it is suggested that the log values for 20 000 h (4.3010 for $\log_{10}$ and 9.9035 for $\log_e$) and 1000 h (3.0000 for $\log_{10}$ and 6.9078 for $\log_e$) be used for Y in Eq. (3). Either $\log_{10}$ or $\log_e$ may be used, depending on the calculator used. These values will provide enough space between the two temperature-point values for accurately drawing in the regression line and are also conveniently located on the log hours scale.

Table 2 can be used in making the calculations. It gives the commonly used test temperatures in degrees Celsius, their reciprocal values in kelvins, and the squares of these reciprocals.

The sample calculation in Table 3 uses data for NRL twist combination 10, which is found on Sheet 1, Column 3 (listing number) of Table A1. The hours-of-life data represent the fifth and sixth failures at each test temperature, using the recommended median truncated data method. However, the formulas can also be used for any number of end-of-life measurements at any number of test temperatures. The calculated regression line and the individual hours-of-life data points at each test temperature are given in Fig. 39.

Table 2—Temperatures and Equivalents

Temperature (°C)	X	X^2 ($\times 10^6$)	Temperature (°C)	X	X^2 ($\times 10^6$)
105	0.002646	7.0013	185	0.002183	4.7655
125	0.002513	6.3152	190	0.002160	4.6656
130	0.002481	6.1554	200	0.002114	4.4690
140	0.002421	5.8612	220	0.002028	4.1128
150	0.002364	5.5885	230	0.001988	3.9521
155	0.002336	5.4569	240	0.001949	3.7986
160	0.002309	5.3315	250	0.001912	3.6557
165	0.002283	5.2121	260	0.001876	3.5194
170	0.002257	5.0940	280	0.001808	3.2689
175	0.002232	4.9818	300	0.001745	3.0450
180	0.002208	4.8708	320	0.001686	2.8426

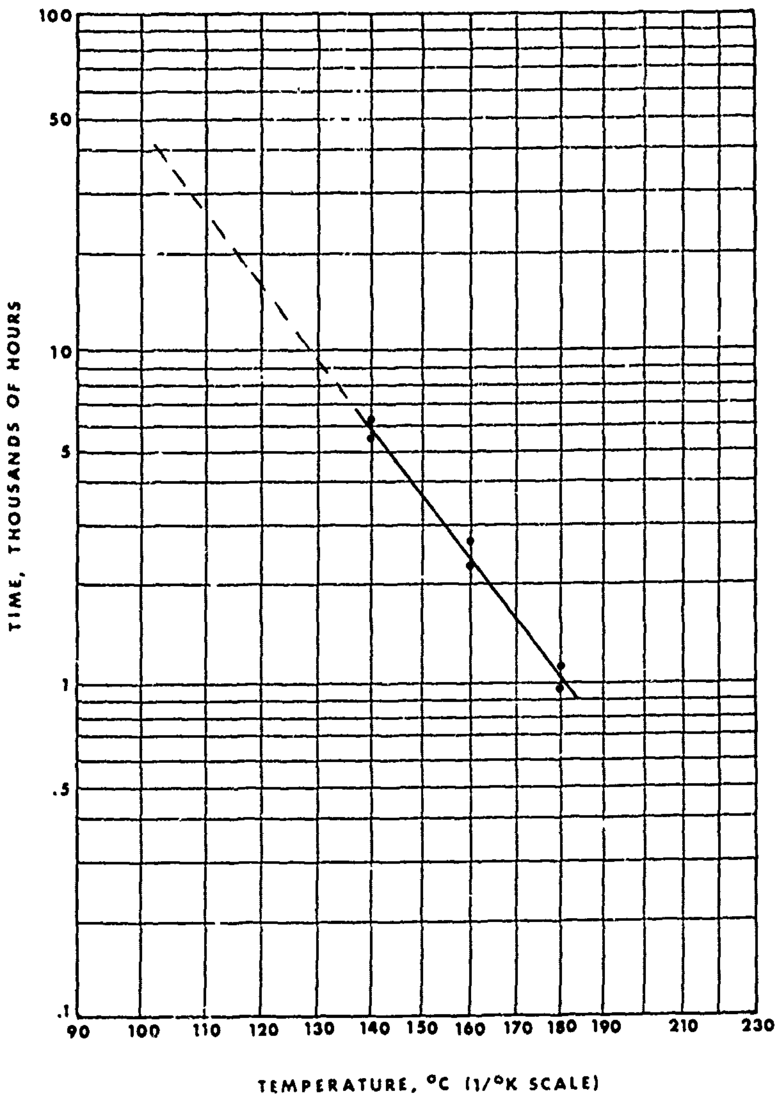


Fig. 39—Calculated regression line and fifth and sixth hours-of-life failure points at each test temperature for twist combination no. 10

Table 3—Sample Calculation

Temperature (°C)	Life (h)	X	X^2 ($\times 10^6$)	Y	XY
140	5548	0.002421	5.8612	8.6212	0.020872
140	5884	0.002421	5.8612	8.6800	0.021014
160	2410	0.002309	5.3315	7.7874	0.017981
160	2744	0.002309	5.3315	7.9172	0.018281
180	960	0.002208	4.8753	6.8669	0.015162
180	1046	0.002208	4.8753	6.9527	0.015352
Σ		0.013876	32.1360	46.8254	0.108662

$N = 6$

$$a = \frac{\Sigma Y - b \Sigma X}{N} = \frac{46.8254 - (8154)(0.013876)}{6} = -11.0533$$

$$b = \frac{N \Sigma XY - \Sigma X \Sigma Y}{N \Sigma X^2 - (\Sigma X)^2} = \frac{(6)(0.108662) - (0.013876)(46.8254)}{(6)(0.000032136) - (0.013876)^2} = 8154$$

$$t \quad (\text{at } 20\,000 \text{ h}) = \frac{b}{Y - a} = \frac{8154}{9.9035 + 11.0533} - 273 = 116°\text{C}$$

$$t \quad (\text{at } 1000 \text{ h}) = \frac{b}{Y - a} = \frac{8154}{6.9078 + 11.0533} - 273 = 181°\text{C}$$

Extrapolation Problems With Nonlinear Life Curves

The fact that problems exist when one attempts to extrapolate data from accelerated thermal aging tests to temperatures in the operating range has been recognized by experts since the early days, when thermal aging tests were first considered as a method for evaluating the thermal life of electrical insulation. More than 25 years ago Dakin [6] pointed out that "if more than one chemical reaction proceeds simultaneously, and if these reactions have different temperature coefficients, a plot of the logarithm of the reaction rate constant or the time to reach a certain state of deterioration against the reciprocal of the absolute temperature may not fall on a straight line."

By 1959 more than 10 years of accumulated data proved that the experts were correct in their early warning that all thermal life data could not be expected to fall on a straight line. The Navy, for one, reported that in its study of motorette systems [10] it found a break in the aging curve at 200°C for polyester magnet wire used in five different insulation systems tested over 3 years. This proof of nonlinearity is graphically illustrated in Fig. 40. At about the same time, Saito and Hino [18] reported "that the relation between log (life) and $1/T$ is not always a straight line." Their statement was based on finding a break in the aging curve, all at the same temperature, for a given film-coated magnet wire when comparing four different thermal evaluation methods. (See Fig. 41.)

By this time several questions were squarely before us. For example: How near the operating temperature need the lowest test temperature point be to reasonably assure us that there is no break in the life curve? If a break appears in the curve at the test temperature range, what should determine whether the data are to be disqualified for extrapolation purposes? Can any other method of determining expected thermal life be considered more reliable? These and other questions were the basis for confusion and many misconceptions in the electrical insulation industry.

Even though extrapolation may lead to inaccuracies, the fact remains that it is the best and most practical approach available today. It is clearly better than attempting to make evaluations using general chemical classifications or using rule-of-thumb methods like the 8- or 10-degree rules. It is obviously far more practical than waiting 10 years or longer for field service trails before recommending or approving a new magnet wire for a particular application. So, if extrapolation is desirable, it is essential to make it on the most accurate basis possible while still taking a reasonable and practical approach to the problem. With this goal in mind, procedures were outlined in the J-W 001177 Military Specification [12]. Here the designated thermal stability test is ASTM D2307. The lowest temperature test point must have an average life of not less than 5000 h and the highest not less than 100 h. The spread between successive temperature points must be at least 20°C, except where certain exceptions are allowed. Should the highest temperature point obtained yield less than 100 h average life, an additional point 10°C lower may be obtained. Extrapolation to determine the classifying temperature (temperature index) is based on the regression line of the three lowest temperature points.

Where nonlinearity exists the procedure graphically illustrated in Fig. 42 is followed. The permissible departure from a straight line is gauged by the difference between the extrapolation of the two lowest temperature points and the regression line of the three lowest points. The differences are measured based on an arbitrary reference line of 40 000 h. (This is not a temperature classification line.) When the extrapolation of the regression line of the three lowest points intercepts the reference line at a point that exceeds *both* 20 000 h and 15°C over that obtained by extrapolating from the two lowest temperature points, an additional temperature point is to be obtained. The time difference (measured vertically downward from the intercept point) and the temperature difference (measured horizontally along the 40 000-h reference line) are represented by distances A and B respectively in Fig. 42. This additional temperature point is to be located at least 10°C below the lowest existing temperature point. To keep the testing time as reasonable as possible, the procedure allows the additional point to be located

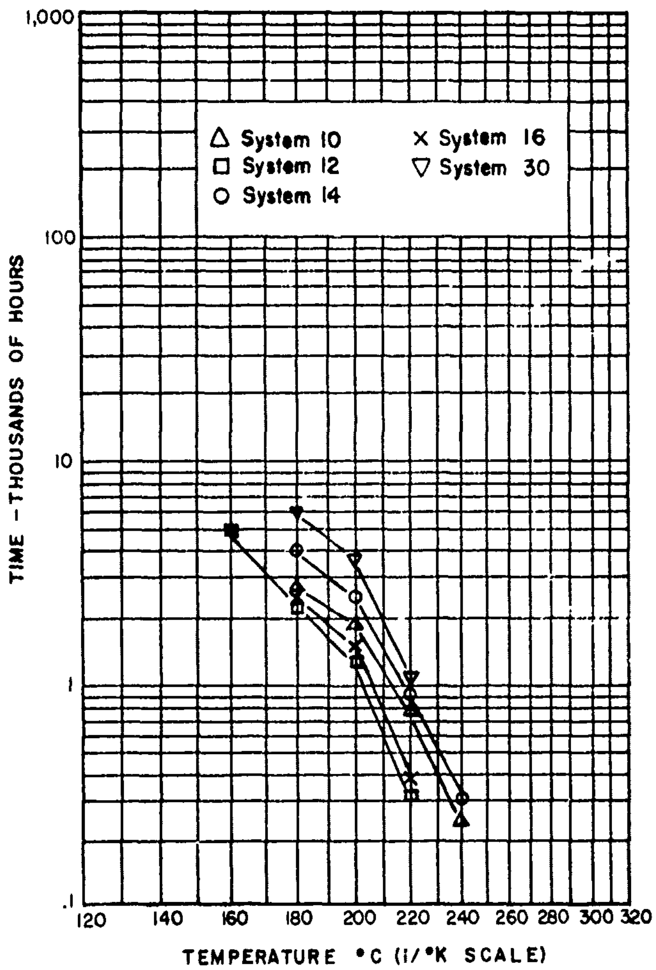


Fig. 40—Aging characteristics of polyester-type magnet wire enamels used in five Navy motorette insulation systems

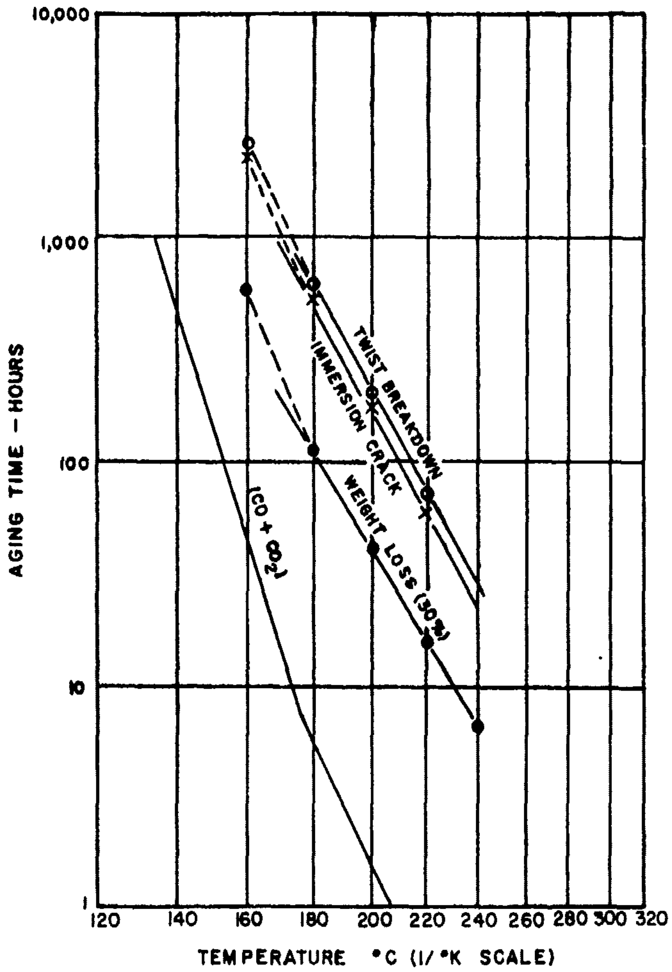


Fig. 41—Comparison of four methods of thermal aging tests using A-formal magnet wire [18]

10°C above the lowest existing temperature point if that point represents an average life of more than 6000 h. However, if it is less than 6000 h the point must be located at least 10°C below that point. After the additional temperature point is obtained, the highest temperature point is discarded; the extrapolation is then based on the regression line of the three lowest points.

This method for handling and interpreting the thermal-life data of electrical insulation appears to offer a good middle-course approach to the overall problem. The procedure is practical and simple and has been specifically designed to meet the needs of electrical insulation evaluation. During the development of this graphical method of testing for acceptable linearity a rather detailed application study was made using the mathematical linearity test outlined in the IEEE 101 standard. In several cases the IEEE 101 method rejected data for nonlinearity while the Navy's graphical test passed the data as acceptable. One consideration the Navy graphical method makes that the IEEE 101

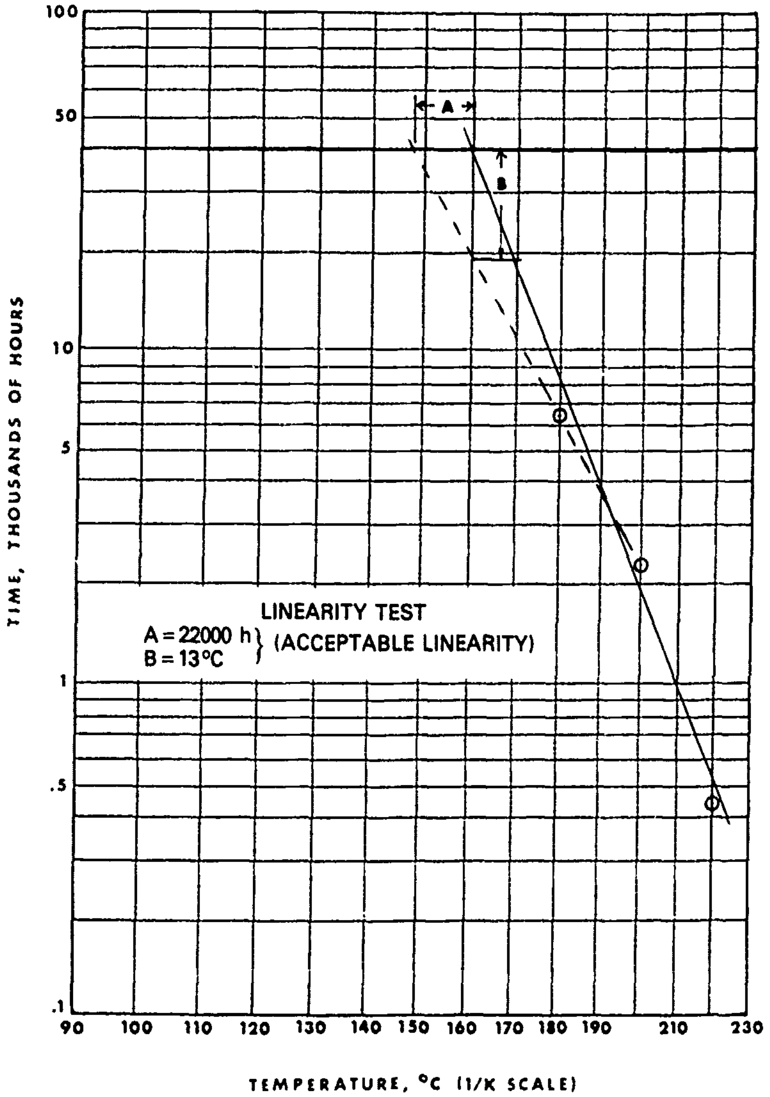


Fig. 42—Example of aging test in which, for acceptable linearity, A must be less than 20 000 h or B must be less than 15°C

method does not is where the lowest temperature point causes a break in linearity in the upward direction. From a practical engineering point of view an upward break in the line contributes to a conservative estimation of life when the regression line of all three temperature points is extrapolated. This can clearly be seen in Fig. 43, where the Navy test accepts the data and the IEEE 101 test rejects it. Figure 44 illustrates a case in which both the Navy and the IEEE 101 test reject the data. Figure 45 is another example of the Navy test accepting the data while the IEEE 101 test rejects it. In this last case the line breaks downward but does not exceed the limit differences in extrapolation (15°C and 20 000 h at the 40 000-h reference line).

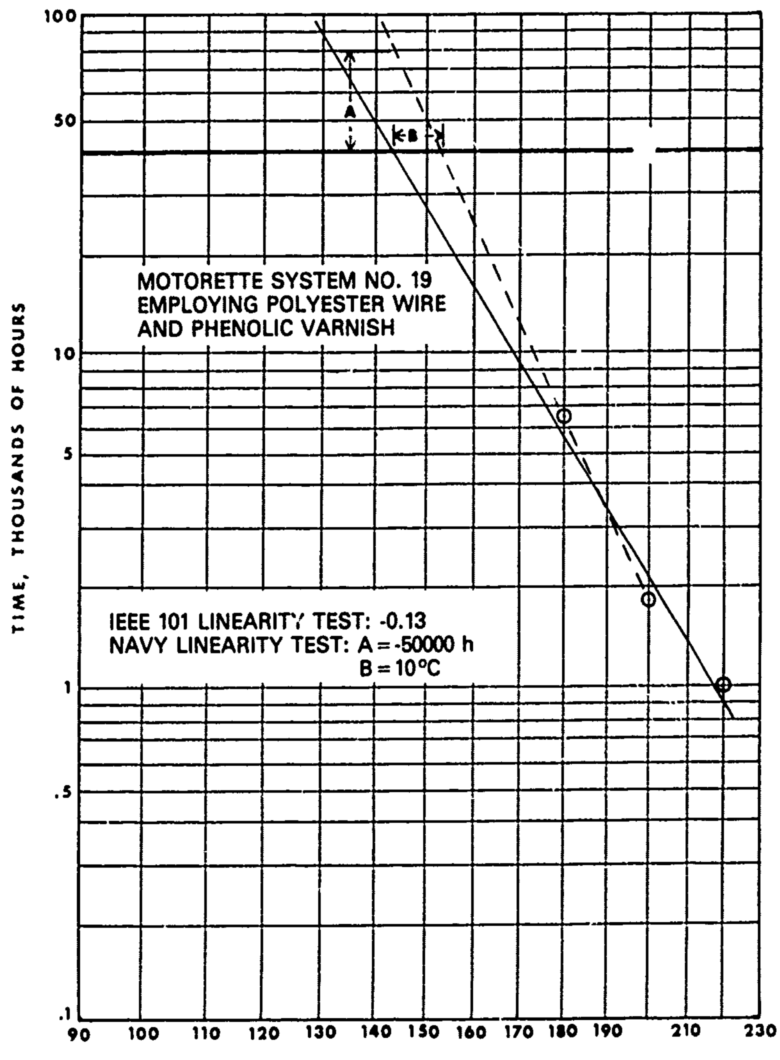


Fig. 43—Example of identical motorette aging data accepted by the Navy linearity test and rejected by the IEEE 101 linearity test

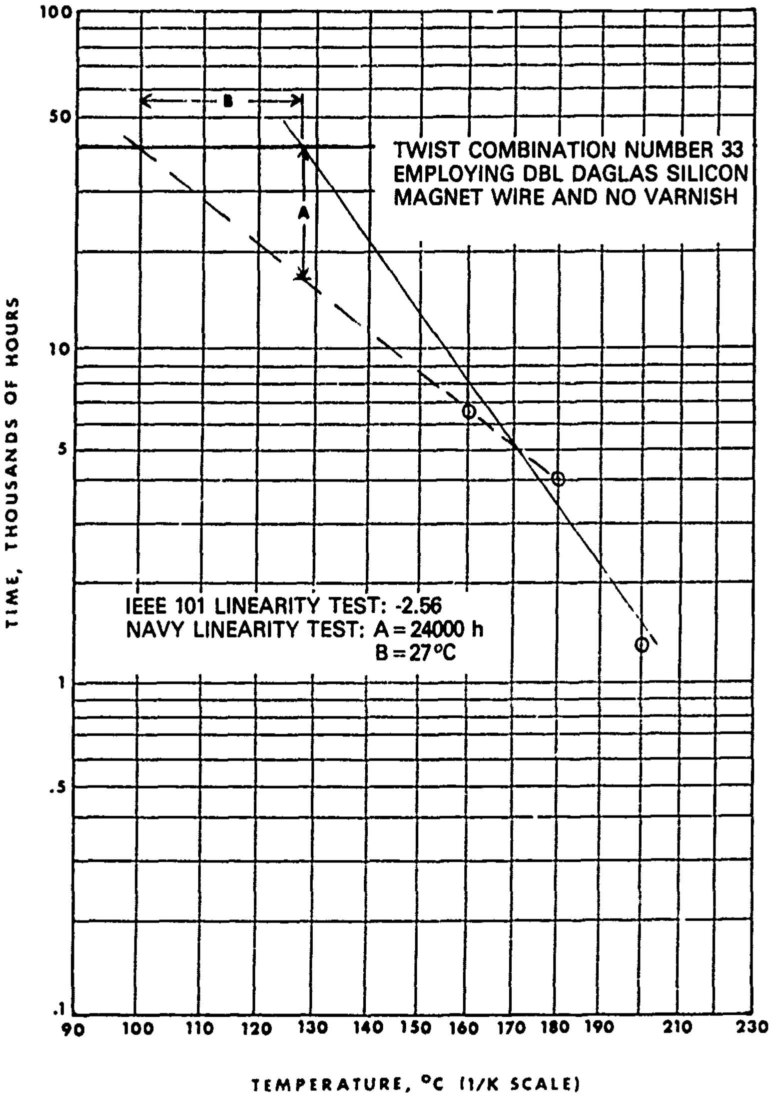


Fig. 44—Example of twist specimen aging data rejected by both Navy and IEEE 101 linearity tests

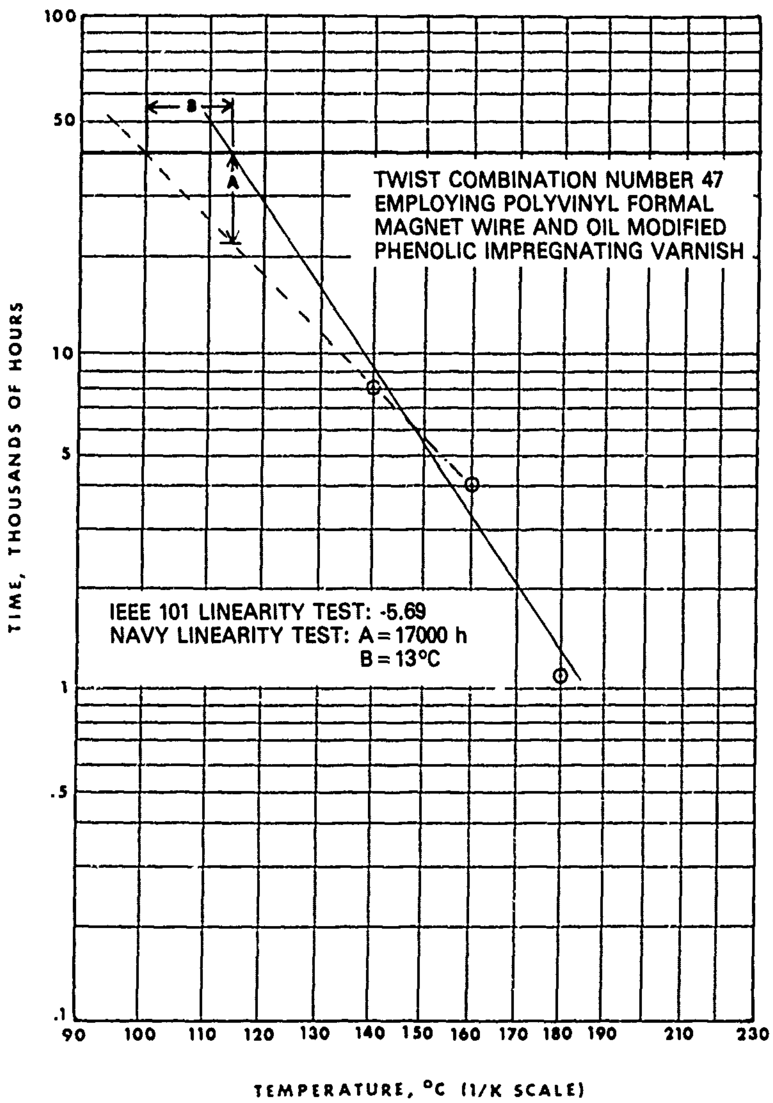


Fig. 45—Example of identical twist specimen aging data accepted by Navy linearity test and rejected by IEEE 101 linearity test

Truncating Data to Shorten Thermal Aging Tests

The standard thermal aging tests for insulation materials (motorette tests and magnet wire twist tests) call for aging 10 specimens until failure at each of three or four temperatures to obtain a life-vs-temperature curve. Valuable time can be saved if a valid estimate of the life at each temperature can be made from data truncated at fewer than all 10 specimens. A statistical analysis was made, using 50 previous thermal evaluations, to study the validity of three different truncated-data methods [19]: the log average of the times for the fifth and sixth failures (method A), an estimate from a probability-plot fit to the first five failure times (method B), and simply the fifth failure time (method C). The methods were found valid, with method A the most and method B the least accurate. All regression lines found by using method A fell within the 95% confidence limits of the complete, or nontruncated, data method, and 90% of the results from the other two methods fell within these limits. If method A had been used when the aging tests were performed an average of 7.4 weeks, or 16.5% of the experimental time, could have been saved with a loss in accuracy of less than 1%. Methods B and C would have saved an average of 10.4 weeks, or 21.7% of the time, with a loss in accuracy of less than 2%. It should be pointed out here that due to the intrinsic characteristics of the test procedures, experimental error itself is conservatively estimated at between 5% and 10%. This alone lends strength to the validity of the truncated data method and its use as a time-saving mechanism.

As an extra precaution regarding the use of truncated data, a later investigation was made of more aging tests, using data from some newer magnet wire insulations not included in the earlier study. Some of these wires yielded a wide spread of data at each temperature point (up to 50% standard deviation) and nonlinear life curves with unusually wide confidence limits. Others exhibited very linear life curves and reasonable small spreads in data (10% to 20% standard deviation) resulting in extremely narrow confidence limits. In all cases truncated data method A gave regression lines that fell well within the required limits of accuracy (0.20% to 1.78% error), and the aging time saved ranged from 3 months to 1 year and 4 months. This additional study furnished conclusive proof that the median (fifth and sixth failure) truncated data method is valid and can cope with such extremes as highly nonlinear or widely dispersed data.

As a result of these studies it is recommended that aging tests using ASTM D2307 and IEEE 117 procedures be stopped after the sixth specimen has failed. This is especially desirable for the lower test temperatures, at which it would take many months or even years to obtain all 10 failures. In circumstances in which accurate confidence limits are required for the regression line, the all-data regression analysis method is used. However, a reasonably close approximation of the confidence limits can be calculated by performing the confidence limit portion of the regression analysis on the basis of 10 failures at each test temperature. This is done by simply substituting the "N" value for the number of specimens that were under test ($N = 30$ in place of $N = 6$ for a three temperature point aging experiment). Also, a "student t" value, appropriate for the number of specimens under test and the percent confidence limit desired, is used. In the several cases in which confidence limits for all the data were compared with those for the truncated data confidence limits, the percent of error did not exceed 3%.

AEROSPACE WIRES

Application of Thermal Evaluation Principles to Aircraft Wires

Functional evaluation by the accelerated procedure was also used to determine service-temperature ratios for insulated power cable and hookup wires used in military aircraft. The program was begun at the request of the Air Force and was continued for the Bureau of Naval Weapons Airborne Equipment Division. The results provided a technology that will considerably reduce weight and bulk in today's aircraft and missiles. To do their part in this effort, electrical engineers must use every available bit of information in designing equipment and circuits to meet these low weight and bulk requirements. Yet in the interest of preservation of a very sizable investment, they must also exercise good judgment in designing to maintain reliability in these circuits throughout the life of each vehicle. Thus, in designing circuit wiring, particularly to carry temporary overloads and pass through high-temperature zones, they must have more information than is now available on deterioration rates of wire insulations, so that they can safely cope with heating conditions above the normal operating temperature ratings of the wires. For expedient application to these design problems, it was determined that such information would be most useful as a graph of wire life vs temperature, accompanied by a simple formula for summing up the deterioration of successive heating cycles to determine the net life of the wire.

To place these objectives on a firm foundation, required a determination of whether the philosophy of functional evaluation and the chemical deterioration rate equation could be universally adapted to describe the characteristics of the many materials and construction variations in insulations used in the aerospace industry for power transmission and hookup wires. By a comprehensive study of one class of wire (MI-W-5086) in its many types of construction forms (using polyvinyl chloride as the primary insulation), the feasibility of this approach was confirmed. Extending the methods to other wire classes using materials such as silicone rubber and polytetrafluoroethylene further confirmed that the degradation rate principles could be applied, and it was demonstrated that various constructions of a particular class of wire could be individually described.

Summary curves of each wire specification group that was studied in this program are presented in Fig. 46. The 10 000-h intercept temperatures presented in Table 4 were taken from these curves and were used to describe the classifying temperatures for each wire insulation grouping described in the respective military specification.

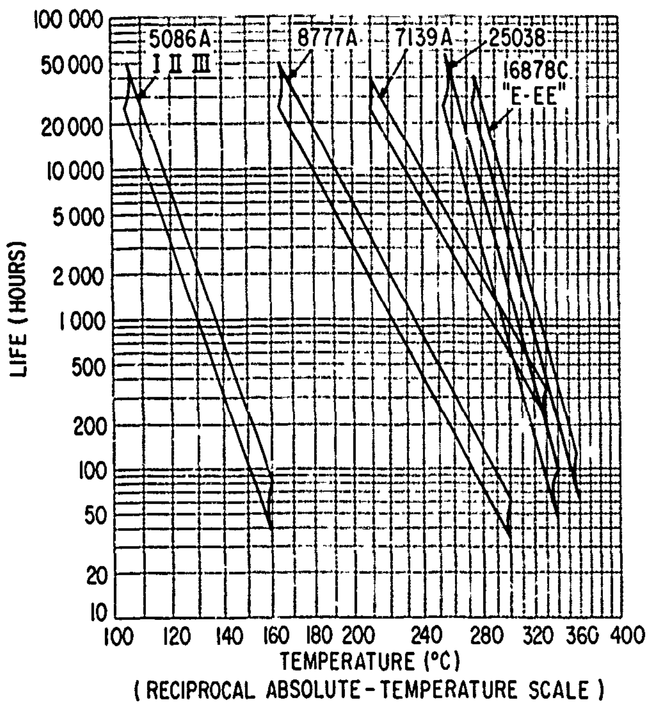


Fig. 46—Graph summarizing ranges of life-temperature curves of military specification wires

Table 4—Intercept Temperatures

Military Specification	Average Classifying Temperature at 10 000 h (°C)
MIL-W—5086A	115
MIL-W-8777A	185
MIL-W-7139A	235
MIL-C-25038	270
MIL-W-16878C, types E and EE	290

Cyclic Temperature-vs-Life Calculations

Most wires in aircraft will, in actual service, operate at a variety of temperatures caused by intermittent current loads and changing ambient conditions. The curves of Fig. 46 can be used to predict the effects of this temperature cycling on insulation life. To compute the life for any heat aging cycle, we find it convenient to treat the relative aging in the manner suggested by Sumner, Stein, and Lockie [20]. This method assigns a factor of unity to the operations at any temperature other than the reference temperature. The relative rate of deterioration is inversely proportional to the computed thermal life at that temperature.

Dividing the logarithmic expression of the chemical rate equation at reference temperature T_0 by that at operating temperature T_1, one obtains the equation of the aging factor-vs-temperature curve as expressed by Whitman [21]:

$$\log R = \log \left(\frac{L_0}{L_1}\right) = B\left(\frac{1}{T_0} - \frac{1}{T_1}\right)$$

or

$$R = \frac{L_0}{L_1}$$

where

R = relative aging factor

B = constant of the material

L_0 = life at reference temperature T_0

L_1 = life at operating temperature T_1

T_0, T_1 = temperature in kelvins (°C + 273).

Consequently, a relative aging factor-vs-temperature curve derived from a straight-line life-temperature curve is also a straight line when plotted on the same coordinate paper, but has a slope of opposite sign. Thus, when the regression curve of life vs temperature for a wire is available, aging time at one temperature is to converted to the equivalent aging time at another temperature by applying the relative aging factor principle.

Suppose we wish to use a wire having the life-temperature curve illustrated in Fig. 47. The life at 105°C is 10 000 h. Figure 48 is the curve of the relative aging factor vs temperature, derived from Fig. 47. The factor is 1.0 at 105°C, the rated maximum continuous temperature of this fictitious wire.

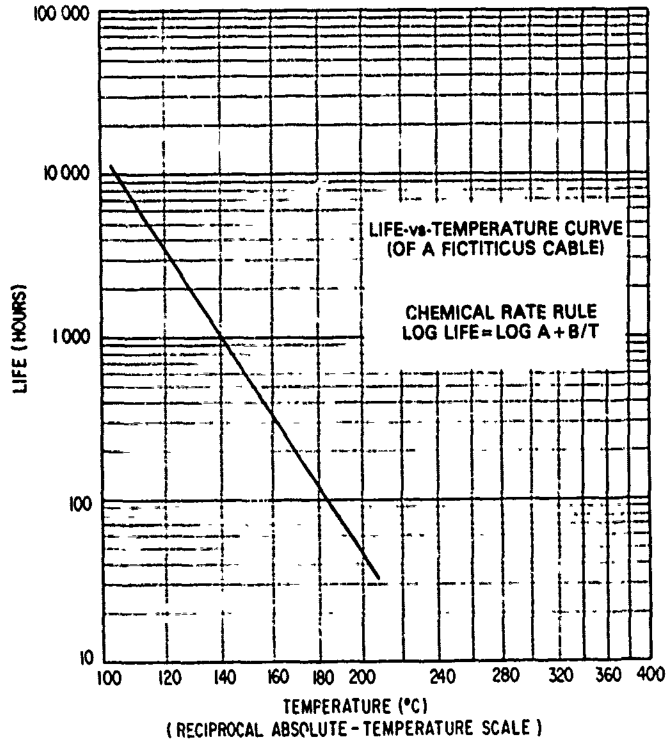


Fig. 47—Life-vs-temperature curve of a fictitious wire insulation

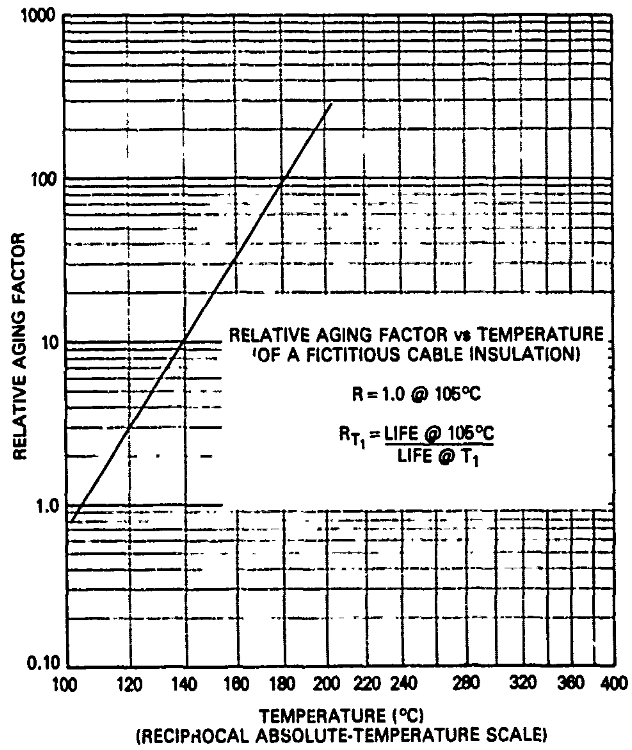


Fig. 48—Curve of relative aging factor vs temperature for a fictitious wire insulation

Applications

Once the regression curve of life vs temperature is established and the curve of the relative aging factor vs temperature is derived, it is possible to predict the effects of temperature cycling on the life of the insulation. An example of the application of this principle to reduce wire weight would be the selection of the maximum wire size for an aircraft electrical circuit required to carry cycles of temporary overloads, such as during landing gear operation. Suppose the specifications require that the reduction in life of the wire due to the overload must not be less than 20% of the life at the rated temperature, and the following performance conditions are specified:

1. Normal current at rated temperature of 105°C (MIL-W-5086A, type I wire)

2. Allowable current during overload state

3. Portion of operating time at overload state = 5%.

To find the maximum steady-state temperature to which the wire insulation can be heated during the overload cycle, let

t_0 = time of operation at 105°C

t_1 = time of overload state = 5% of total time

T_1 = temperature at overload state

R_1 = relative aging factor at T_1

100 = percent life at rated temperature of 105°C.

Expressing the total life available as

$$t_0 + R_1 t_1 = 100\%,$$

and the specified minimum life as

$$t_0 + t_1 = 80\%,$$

solve for R_1 by substitution:

$$(80 - t_1) + R_1 t_1 = 100$$

$$R_1 = \frac{20}{5} + 1 = 5.$$

If we assume that the curve of relative aging factor vs temperature in Fig. 29 represents this type of wire, temperature T_1 at $R_1 = 5$ is 128°C. The maximum wire size that does not exceed a temperature of 128°C while carrying the specified overload current can then be selected (from the time-temperature-current curves representing this type of wire) and installed.

The overload cycle in this example has been treated as rectangular in waveform, assuming that the time of temperature rise is relatively short in comparison to the total time at the maximum temperature during the overload. The problem of a transient temperature rise of a relatively short duration, such as might occur due to a circuit fault, can be solved similarly by expressing the temperature rise and fall vs time as exponential curves. The relative aging time of the cycle would then be calculated by integrating the curves of the instantaneous relative aging vs time.

Three different experiments were conducted in this program with the heat exposure cycles at different schedules and temperatures, and in each test the R-value as calculated in the above example was experimentally verified. Thus, it was demonstrated that it is possible to apply the relative aging factor calculation to convert aging temperature cycles to equivalent aging at any one temperature and thus predict the life of wire for cycling service conditions. When overloads, causing rises to higher temperatures, occur in known service cycles, it is possible to calculate the number of cycles that can be safely expected of the wire.

FUTURE WORK ON PROBLEMS IN NEED OF SOLUTION

Today thermal aging technology is approaching maturity and is being used by both industry and government in insulation systems design and materials specifications. The universality of application, however, means not that the problems have all been eliminated, but merely that the need is so great that an imperfect tool is better than none.

In the main, what has been accomplished to date is the development of test procedures that define and simulate a functional model of the insulation system of interest, and correspondingly of the appropriate environment and failure criterion. These procedures have permitted the development of standards for obtaining index ratings of materials and classifications ratings for systems. This obviously aids and encourages design of new systems.

While progress in thermal aging has been significant, the problems remaining are equally significant. The authors commend the following four areas for continued exploration.

Humidification

The humid environment is still one of the most troublesome to simulate and equally difficult to standardize. Industry has used humidification with condensation with resulting large scatter in results. The Navy, in the effort to reduce the spread in data, has used humidification without visible condensation. While the latter has yielded reproducible results, it has been at the cost of increased testing time. This impasse was resolved in the IEEE 117 Working Group with the development of the condensation chamber previously described. While this provides considerably improved humidification, problems remain. Some of these problems are the ratio of surface humidification to bulk humidification, the duration of humidification, and the method of measuring. When these questions are answered, some standardization of humidification can take place.

Failure Criteria

Failure criteria may have to be broadened for specific use; aging phenomenon may not always dictate the end of life of insulation systems. Voltage breakdown due to surface tracking or corona, mechanical rupture or deformation of insulation, and deterioration due to an inimical chemical or to dust environments may well determine the end of useful life before full thermal degradation sets in.

Duration of Tests

Testing at present takes entirely too long and is too expensive. Some aging results are influenced by the overly high temperature of tests, at which chemical kinetics are not the same as at operating temperatures. Work should now turn to measuring the degradation near or at operating temperature for a relatively brief period (hours or a few days) and integrating the rate over the expected life of the system.

Combined Environments

In addition to the thermal environment, insulation life is affected by such other environments as chemical fumes, vacuum, and radiation. The advent of the nuclear and space age has injected the parameter of radiation into design consideration. It is important to know and be able to measure the effects of radiation on the electrical and life properties of insulation. These effects are not always predictable because radiation induces simultaneously two opposite events in a polymer; on one hand it links polymer chains together, increasing the molecular weight by "cross linking," while on the other hand the polymer chain is fractured by "chainscission," causing degradation. The rate balance between these two events determines if a material improves or degrades in some specified characteristic. However, this equilibrium point is also a function of temperature. Thus, while a material at a given temperature may be improved in some of its characteristics by radiation, the same material under the same radiation conditions may degrade if the temperature is changed.

This was demonstrated by Campbell [22] when he exposed magnet wire to gamma radiation, then aged the wire at a given temperature. He repeated these exposures on similar wires but combined the environments; the results were very different. For example, the simultaneous aging at high temperatures in gamma radiation of a polyimide, a polyvinyl formal, and a polysiloxane produced considerably longer lifetimes than simple thermal aging at the same temperature. On the other hand, polytetrafluoroethylene deteriorated much more rapidly under simultaneous heat and radiation.

This means that test conditions must be designed to simulate service environments, if results are to be meaningful. The synergism of heat and radiation cannot be overlooked. While radiation was used as the second environment in illustrating this point, this applies to any combination of environments. Effort should be devoted to expanding test procedures toward combined environments where physical, chemical, mechanical, humidity, vacuum, and radiation conditions, etc., are singly or in combination the prime cause of failure.

In conclusion, one can infer that the posed questions in themselves reveal the tangible and considerable progress that has been made in this field. The statement of remaining problems is not so fundamental as to suggest that little has been done; they are on the other hand specific enough to reveal the considerable command the profession has in thermal aging. It is hoped that satisfaction with the present state of the art will not delay or set aside investigation of these and other related issues.

CONCLUSIONS AND RECOMMENDATIONS

As a result of this study the following conclusions and recommendations are made.

1. The magnet wire twist and motorette insulation systems procedures have had sufficient successful history, in both industrial and governmental laboratories, to be continued as standard procedures.

2. The humidity cycle is a reliable diagnostic tool in determining the end of thermal life of motorette insulation systems. However, the following considerations should be taken into account.

a. Specimens should be exposed for at least 60 h when humidity without visible condensation is employed. However, the minimum exposure time can be reduced to 48 h when condensation chamber is used.

b. Years of Navy experience have proved that humidification without visible condensation provides a reliable method for obtaining uniform and reproducible results in evaluating a wide range of insulation systems.

c. Where overall aging time is to be minimized, humidification with visible condensation is recommended provided the IEEE 117 Test Procedure is strictly adhered to.

3. The median method for truncating data has been proven valid; it saves substantial aging time (up to 20%). It is strongly recommended that this time saving method be used in future thermal aging studies.

4. As a result of recent field and laboratory experience the Navy's classifying life-line benchmark should be established at 20 000 h, in lieu of the original 40 000 h, when considering data from the magnet wire twist test and the motorette procedure using humidification without visible condensation.

5. In future work the following should be pursued.

a. Most electrical insulation is, in reality, subject to combinations of aging factors, such as voltage and temperature or radiation and temperature. It is strongly urged that an adequate understanding of the physics and chemistry of aging be acquired, so that multistress aging can be predicted and evaluation procedures developed.

b. The interrelationships or mutual influences of materials in the presence of others should be studied. Experience indicates that properties of combined electrical insulations do not necessarily reflect the characteristics of each material separately.

c. It is recommended that more sensitive measuring techniques be explored. This should be aimed at assessing the rate of aging close to the operating temperature and to shortening test periods (possibly to one month).

d. Further study of humidity should be pursued, particularly in the areas of surface-to-bulk ratio effects, simplifying procedures and increasing reproducibility.

e. With a better knowledge of aging phenomena, possible nondestructive evaluation procedures should be explored and developed.

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Appendix A

USE OF COMPUTER READOUT TABLES A1 AND A2

Table A1 provides information on the computer regression analysis of temperature-life data for magnet wire twist evaluations, and Table A2 provides the same information for motorette systems. As an aid to finding specific magnet wire combinations or motorette systems in the two tables, indexes are furnished. The first column of the index lists the sheet (page) number of the table and the second column the listing number for each twist combination or motorette system. The fourth and fifth columns list the index key numbers to the generic names of the magnet wire insulations and varnishes used in each twist combination and motorette system. These are given in Tables A3 and A4. Each sheet of Tables A1 and A2 has 12 listing numbers, 6 on the first line of the top half and 6 on the first line of the bottom half. In columns under these numbers are given the three lowest test temperatures (1, 2, and 3), the 95% lower-only confidence limit at these three temperatures, and the mean regression line hours for temperature 3 (furnished to aid in plotting the regression line). Below this are the regression line temperature index values for 20 000, 30 000, and 40 000 h, along with the corresponding values for the lower-only confidence limit.

While 254 twist combinations and 62 motorette systems are listed in Tables A1 and A2, the number evaluated was greater than this. Many of the earlier evaluations did not meet the more stringent requirements later set forth by the Navy for thermal evaluation of electrical insulations, particularly in terms of the minimum hours of life at the lowest test temperature and the additional temperature points required for extrapolation when the aging data did not meet the linearity requirements. In addition, some of the twist combinations and motorette systems were used in special side studies, and this data did not lend itself to the type of processing suitable for the tables.

It will be noted that in Tables A1 and A2 the 95% lower-only confidence limits were calculated and listed in favor of the 95% upper and lower confidence limits. This was done, as recommended in IEEE 101, because it is more meaningful to determine to a 95% degree of confidence the lower bound of the mean regression life at a given temperature. Since the lower-only confidence limit yields a longer life at a given temperature (or a higher temperature for a given life) for the same degree of confidence than a two-sided confidence limit it is more favorable to use the lower-only limit.

Index to Computer Data Sheets (Table A1) and Twist Sample Identification

Sheet Number	Listing Number	Combination Number	Wire Insulation	Varnish	AWG Size
1	1	8	A	NONE	20
1	2	9	A	2A	20
1	3	10	A	2B	20
1	4	46	A	2D	20
1	5	50	A	2F	18
1	6	51	A	2F	18
1	7	52	A	2F	18
1	8	11	A	5A	20
1	9	47	A	2D	20
1	10	135F	A	2A	18
1	11	135B	A	2A	18
1	12	135C	A	2A	18
2	13	09	B-1	2A	18
2	14	16	B-1	NONE	20
2	15	17	B-1	3A	20
2	16	18	B-1	3A	20
2	17	45	B-1	4A	20
2	18	65	C-1	NONE	20
2	19	66	C-1	4A	20
2	20	67	C-1	10A	20
2	21	123	C-1	NONE	20
2	22	124	C-1	4A	20
2	23	125	C-1	NONE	20
2	24	126	C-1	4B	20
3	25	127	D-1	NONE	20
3	26	71	B-4	NONE	20
3	27	72	B-4	4A	20
3	28	73	B-4	10A	20
3	29	68	D-2	NONE	18
3	30	69	D-2	4A	18
3	31	70	D-2	10A	18
3	32	98	D-2	NONE	20
3	33	99	D-2	10A	20
3	34	82	D-2	4E	18
3	35	100	D-2	4E	20
3	36	161	D-2	4E	20
4	37	83	D-2	(2 DIPS)	18
4	38	272	G-1	NONE	20
4	39	273	G-1	4E	20
4	40	274	G-1	4D	20
4	41	275	G-1	5E	20
4	42	276	G-1	4C	20
4	43	277	G-1	2C	20
4	44	278	G-1	4F	20
4	45	198	D-2	5C	20

Index to Computer Data Sheets (Table A1) and Twist Sample Identification (Continued)

Sheet Number	Listing Number	Combination Number	Wire Insulation	Varnish	AWG Size
4	46	119	D-2	5D	20
4	47	321	G-1	NONE	20
4	48	322	G-1	NONE	20
5	49	373	G-1	9A	19
5	50	340	G-1	NONE	18
5	51	341	G-2	4E	18
5	52	342	G-2	2E	18
5	53	343	G-2	6B	18
5	54	344	G-2	10A	18
5	55	303	H-1	11A	20
5	56	305	H-1	NONE	20
5	57	306	H-1	NONE	20
5	58	307	H-1	NONE	20
5	59	308	H-1	NONE	20
5	60	309	H-1	4E	20
6	61	310	H-1	4E	20
6	62	361	H-1	4F	20
6	63	362	H-1	9A	20
6	64	259	G-4	NONE	20
6	65	260	G-4	4E	20
6	66	261	G-4	10A	20
6	67	262	G-4	7A	20
6	68	263	G-5	NONE	20
6	69	264	G-5	4E	20
6	70	265	G-5	10A	20
6	71	266	G-5	7A	20
6	72	283	G-5	6B	20
7	73	285	G-5	6B	20
7	74	286	G-5	6B	20
7	75	267	G-6	NONE	20
7	76	268	G-6	4E	20
7	77	269	G-6	10A	20
7	78	270	G-6	7A	20
7	79	287	G-6	6B	20
7	80	288	G-6	2D	20
7	81	253	P-1	4E	20
7	82	252	P-1	6B	20
7	83	251	P-1	10A	18
7	84	250	P-1	2D	18
8	85	249	P-1	NONE	18
8	86	356	H-6	NONE	20
8	87	357	H-7	NONE	20
8	88	358	H-8	NONE	20
8	89	359	H-9	NONE	20
8	90	232	P-2	NONE	20
8	91	233	P-2	2D	20

Index to Computer Data Sheets (Table A1) and Twist Sample Identification (Continued)

Sheet Number	Listing Number	Combination Number	Wire Insulation	Varnish	AWG Size
8	92	234	P-2	10A	20
8	93	235	P-2	6B	20
8	94	236	P-2	4E	20
8	95	295	P-2	7A	20
8	96	302	P-2	7A	20
9	97	06	B-2	5A	20
9	98	24	B-2	NONE	20
9	99	25	B-2	2A	20
9	100	19	B-3	NONE	20
9	101	015	B-3	4E	20
9	102	016	B-3	2A	20
9	103	86	H-1	NONE	20
9	104	87	H-1	10A	20
9	105	89	H-1	10B	20
9	106	90	H-3	10B	20
9	107	91	H-1	13A	20
9	108	271	H-1	4E	20
10	109	206	H-1	NONE	20
10	110	201	H-1	10A	20
10	111	208	H-1	13C	20
10	112	76	H-2	NONE	20
10	113	88	H-2	13B	20
10	114	294	H-1	10A	36
10	115	279	E-2	4E	20
10	116	280	E-2	10A	20
10	117	281	E-2	2D	20
10	118	282	E-2	6B	20
10	119	289	E-2	NONE	20
10	120	301	E-2	7A	18
11	121	298	J-1	NONE	24
11	122	299	J-1	NONE	24
11	123	345	K-1	NONE	18
11	124	346	K-1	4E	18
11	125	347	J-2	2D	18
11	126	348	K-1	6B	18
11	127	349	J-2	10A	18
11	128	350	L-1	NONE	20
11	129	351	L-1	2E	20
11	130	352	L-1	4E	20
11	131	353	L-1	7A	20
11	132	354	L-1	10A	20
12	133	355	L-1	6B	20
12	134	325	M-1	NONE	18
12	135	327	M-1	6B	18
12	136	329	M-1	10A	18

Index to Computer Data Sheets (Table A1) and Twist Sample Identification (Continued)

Sheet Number	Listing Number	Combination Number	Wire Insulation	Varnish	AWG Size
12	137	330	M-1	7A	18
12	138	371	M-1	10A	20
12	139	372	N-1	10A	20
12	140	374	M-1	NONE	20
12	141	375	M-1	NONE	20
12	142	363	H-4	NONE	18
12	143	364	H-4	4E	18
12	144	365	H-4	10A	18
13	145	217	H-5	NONE	20
13	146	237	0	NONE	20
13	147	238	0	6B	20
13	148	239	0	7A	20
13	149	240	0	4E	20
13	150	241	0	2D	20
13	151	242	0	10A	20
13	152	338	0	12A	20
13	153	290	H-10	NONE	20
13	154	291	H-10	NONE	20
13	155	185	I	NONE	20
13	156	186	I	10A	20
14	157	188	I	4E	20
14	158	189	I	14A	20
14	159	313	I	NONE	20
14	160	314	I	NONE	20
14	161	315	I	NONE	20
14	162	317	I	4E	20
14	163	300	M-2	7A	20
14	164	254	M-2	NONE	20
14	165	255	M-2	2D	20
14	166	256	M-2	10A	20
14	167	257	M-2	6B	20
14	168	258	M-2	4E	20
15	169	132	H-1	NONE	20
15	170	133	H-1	13B	18
15	171	148	H-1	8A	20
15	172	177	H-1	13C	20
15	173	293	H-1	10A	32
15	174	139	E-1	NONE	23
15	175	140	E-1	2C	23
15	176	141	E-1	10A	23
15	177	154	F-2	NONE	20
15	178	155	F-2	10A	20
15	179	156	H-1	NONE	20
15	180	157	H-1	9A	20
16	181	158	H-1	10A	20

Index to Computer Data Sheets (Table A1) and Twist Sample Identification (Continued)

Sheet Number	Listing Number	Combination Number	Wire Insulation	Varnish	AWG Size
16	182	159	H-1	6B	20
16	183	160	H-1	4E	20
16	184	292	H-1	10A	28
16	185	95	D-3	NONE	20
16	186	96	D-3	10A	20
16	187	97	D-3	4A	20
16	188	108	D-3	NONE	20
16	189	109	D-3	10A	20
16	190	57	B-7	4D	18
16	191	84	H-3	NONE	20
16	192	85	H-3	10A	20
17	193	92	H-3	13A	20
17	194	366	L-3	NONE	20
17	195	368	L-4	NONE	20
17	196	370	L-5	NONE	20
17	197	367	L-2	NONE	20
17	198	55	B-7	4D	18
17	199	56	B-7	4D	18
17	200	101	S	NONE	20
17	201	102	S	4A	20
17	202	103	S	10A	20
17	203	104	T	NONE	20
17	204	105	T	10A	20
18	205	106	U	NONE	20
18	206	107	U	10A	20
18	207	116	U	NONE	20
18	208	117	S	4A	20
18	209	118	S	10A	20
18	210	119	T	NONE	20
18	211	120	T	10A	20
18	212	121	U	NONE	20
18	213	122	U	10A	20
18	214	130	Q	NONE	20
18	215	131	Q	2C	20
18	216	136	B-6	NONE	20
19	217	137	B-6	2C	20
19	218	138	B-6	6C	20
19	219	2	W	10A	18
19	220	3	W	4D	18
19	221	34	W	NONE	18
19	222	07	V	10A	20
19	223	013	V	2A	20
19	224	014	Y-1	10A	20
19	225	12	Y-1	NONE	20
19	226	13	Y-1	6A	20

Index to Computer Data Sheets (Table A1) and Twist Sample Identification (Continued)

Sheet Number	Listing Number	Combination Number	Wire Insulation	Varnish	AWG Size
19	227	14	Y-2	NONE	20
19	228	15	Y-2	10A	20
20	229	010	Z-1	5A	20
20	230	22	Z-1	6A	20
20	231	58	Z-2	NONE	18
20	232	59	Z-2	2A	18
20	233	60	Z-2	2C	18
20	234	61	Z-2	6A	18
20	235	62	Z-2	10A	18
20	236	80	Z-3	NONE	18
20	237	81	Z-3	2G	18
20	238	017	X	10A	18
20	239	018	X	2A	18
20	240	022	X	2A	20
21	241	023	C-5	5A	20
21	242	024	C-5	10A	20
21	243	23	C-5	NONE	20
21	244	31	B-5	NONE	20
21	245	32	B-5	2B	20
21	246	41	B-5	2A	20
21	247	43	C-2	4E	20
21	248	44	C-2	NONE	20
21	249	74	R	NONE	20
21	250	75	R	15A	20
21	251	78	Y-2	10B	20
21	252	79	Y-2	NONE	20
22	253	128	C-4	NONE	20
22	254	129	C-4	2C	20

Table A1—Computer Readout Data, (Sheet 1)

LISTING NUMBER		1	2	3	4	5	6
COMBINATION NUMBER		8	9	10	46	50	51
3 LOWEST	1	120	130	140	140	140	140
TEST	2	140	140	160	160	160	160
TEMPERATURES	3	160	160	180	180	180	180
LOG. AVG. LIFE	1	7644	10584	5714	4788	3864	4216
AT TEST	2	2000	4520	2572	1587	756	1558
TEMP.(HRS.)	3	582	1402	1002	756	612	568
95% L.C.L.ONLY	1	6903	9412	5532	4209	2318	4186
VALUES(HRS.)	2	1918	4843	2332	1691	1066	1492
@TEMPS. 1,2&3	3	527	1268	975	663	363	565
MEAN REG. LINE	3	584	1357	1042	720	485	579
20,000 HOUR	TEMP.INDEX	107	120	116	113	107	114
TEMP. VAL.(C)	L.C.L.	104	119	113	109	88	113
30,000 HOUR	TEMP.INDEX	102	115	109	106	100	107
TEMP. VAL.(C)	L.C.L.	99	113	105	102	79	106
40,000 HOUR	TEMP.INDEX	98	111	103	101	95	103
TEMP. VAL.(C)	L.C.L.	95	110	100	97	74	102

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LISTING NUMBER		7	8	9	10	11	12
COMBINATIØN NUMBER		52	11	47	135F	135B	135C
3 LØWEST TEST TEMPERATURES	1	140	140	140	140	140	140
	2	160	160	160	160	160	160
	3	180	180	180	180	180	180
LØG. AVG. LIFE AT TEST TEMP.(HRS.)	1	3400	11219	8277	6039	4692	5365
	2	1564	5162	3696	1452	1284	1365
	3	566	1096	1173	684	612	503
95% L.C.L.ØNLY VALUES(HRS.) @TEMPS. 1,2&3	1	3330	10558	7949	4834	3905	4728
	2	1373	3596	3085	1680	1442	1446
	3	560	1051	1137	545	507	442
MEAN REG. LINE	3	600	1278	1265	619	565	480
20,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	108	133	125	120	115	120
	L.C.L.	104	128	122	115	110	118
30,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	101	127	118	114	108	115
	L.C.L.	97	121	114	108	103	112
40,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	96	123	114	109	104	111
	L.C.L.	92	117	109	104	99	108

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Table A1—Computer Readout Data, (Sheet 2) (Continued)

LISTING NUMBER		13	14	15	16	17	18
COMBINATION NUMBER		09	16	17	18	45	65
3 LOWEST	1	160	180	160	160	180	200
TEST	2	180	200	180	180	200	220
TEMPERATURES	3	200	220	200	200	220	240
LOG. AVG. LIFE	1	15735	9912	28572	29740	10344	13752
AT TEST	2	4894	3716	7056	7382	3849	2684
TEMP.(HRS.)	3	2742	552	3288	3116	912	227
95% L.C.L.ONLY	1	12818	9258	23194	25211	9896	12782
VALUES(HRS.)	2	5564	2419	8100	8248	3059	1774
@TEMPS. 1,2&3	3	2224	526	2656	2631	882	215
MEAN REG. LINE	3	2509	662	2994	2891	1004	270
20,000 HOUR TEMP.INDEX		153	173	165	165	171	198
TEMP. VAL.(C) L.C.L.		150	169	163	164	168	196
30,000 HOUR TEMP.INDEX		145	168	158	159	166	194
TEMP. VAL.(C) L.C.L.		141	163	155	157	162	192
40,000 HOUR TEMP.INDEX		140	165	153	154	162	192
TEMP. VAL.(C) L.C.L.		134	159	150	152	158	189

LISTING NUMBER		19	20	21	22	23	24
COMBINATIØN NUMBER		66	67	123	1[illegible]	125	126
3 LØWEST	1	200	190	200	200	200	200
TEST	2	220	200	220	220	220	220
TEMPERATURES	3	240	220	240	240	240	240
LØG. AVG. LIFE	1	10576	14200	12270	8736	15557	7981
AT TEST	2	3970	6534	1425	2473	1848	1596
TEMP.(HRS.)	3	468	3190	311	508	564	408
95% L.C.L.ØNLY	1	9746	11516	10133	8412	11409	7483
VALUES(HRS.)	2	2347	7386	1609	2062	2275	1639
@TEMPS. 1,2&3	3	442	2669	256	494	411	382
MEAN REG. LINE	3	585	3011	286	548	490	399
20,000 HØUR TEMP.INDEX		195	181	194	190	196	189
TEMP. VAL.(C) L.C.L.		190	178	193	188	193	188
30,000 HØUR TEMP.INDEX		190	174	190	185	191	184
TEMP. VAL.(C) L.C.L.		184	169	189	183	188	183
40,000 HØUR TEMP.INDEX		187	169	188	182	188	181
TEMP. VAL.(C) L.C.L.		181	163	186	179	185	180

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Table A1—Computer Readout Data, (Sheet 3) (Continued)

LISTING NUMBER		25	26	27	28	29	30
COMBINATION NUMBER		127	71	72	73	68	69
3 LOWEST	1	200	180	180	200	190	180
TEST	2	220	200	200	220	200	200
TEMPERATURES	3	240	220	220	240	220	220
LOG. AVG. LIFE	1	9509	45882	27772	7403	13933	20606
AT TEST	2	1848	3925	4357	2047	4493	2744
TEMP.(HRS.)	3	408	2572	2959	102	1342	1352
95% L.C.L.ONLY	1	9488	22008	16374	6532	10711	13014
VALUES(HRS.)	2	1846	6418	6191	943	5221	3726
@TEMPS. 1,2&3	3	407	1213	1724	93	1071	845
MEAN REG. LINE	3	408	1844	2332	141	1249	1099
20,000 HOUR TEMP.INDEX		191	187	182	194	184	178
TEMP. VAL.(C) L.C.L.		191	182	176	188	181	173
30,000 HOUR TEMP.INDEX		187	182	175	191	179	173
TEMP. VAL.(C) L.C.L.		187	175	167	1_4	176	167
40,000 HOUR TEMP.INDEX		184	178	171	188	176	169
TEMP. VAL.(C) L.C.L.		184	170	161	182	172	162

LISTING NUMBER		31	32	33	34	35	36
COMBINATION NUMBER		70	98	99	82	100	161
3 LOWEST	1	200	200	200	200	200	200
TEST	2	220	220	220	220	220	220
TEMPERATURES	3	240	240	240	240	240	240
LOG. AVG. LIFE	1	6959	9036	9708	6502	7632	6644
AT TEST	2	1492	2924	2356	1584	2356	2251
TEMP.(HRS.)	3	803	504	360	247	624	576
95% L.C.L.ONLY	1	4929	8605	9333	6267	7480	6485
VALUES(HRS.)	2	1832	2153	1845	1250	2119	1927
@TEMPS. 1,2&3	3	565	487	350	241	614	566
MEAN REG. LINE	3	695	574	399	273	652	615
20,000 HOUR TEMP.INDEX		181	191	193	189	187	185
TEMP. VAL.(C) L.C.L.		173	188	191	186	185	183
30,000 HOUR TEMP.INDEX		174	187	189	184	181	179
TEMP. VAL.(C) L.C.L.		165	183	186	182	180	177
40,000 HOUR TEMP.INDEX		170	183	186	181	177	175
TEMP. VAL.(C) L.C.L.		160	179	183	178	175	172

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Table A1—Computer Readout Data, (Sheet 4) (Continued)

LISTING NUMBER		37	38	39	40	41	42
COMBINATION NUMBER		83	272	273	274	275	276
3 LOWEST	1	200	190	190	190	190	190
TEST	2	220	200	200	200	200	200
TEMPERATURES	3	240	220	220	220	220	220
LOG. AVG. LIFE	1	8101	16710	9477	16509	11879	11077
AT TEST	2	2357	8122	6580	8225	8321	8217
TEMP.(HRS.)	3	396	1428	2014	1260	1596	1932
95% L.C.L.ONLY	1	7762	16779	9499	16610	12004	11183
VALUES(HRS.)	2	1791	7285	5704	7002	6296	6389
@TEMPS. 1,2&3	3	384	1383	1924	1201	1469	1793
MEAN REG. LINE	3	445	1471	2094	1317	1723	2070
20,000 HOUR TEMP.INDEX		190	189	178	189	185	183
TEMP. VAL.(C) L.C.L.		188	188	176	188	182	180
30,000 HOUR TEMP.INDEX		186	184	172	185	180	177
TEMP. VAL.(C) L.C.L.		182	183	169	183	176	173
40,000 HOUR TEMP.INDEX		182	181	167	182	176	173
TEMP. VAL.(C) L.C.L.		179	180	163	180	172	168

LISTING NUMBER		43	44	45	46	47	48
COMBINATION NUMBER		277	278	198	199	321	322
3 LOWEST	1	190	190	200	200	190	190
TEST	2	200	200	220	220	200	200
TEMPERATURES	3	220	220	240	240	220	220
LOG. AVG. LIFE	1	10871	16710	5520	5520	16943	12976
AT TEST	2	6188	9202	1932	1932	7439	3791
TEMP.(HRS.)	3	1491	1848	516	468	1161	1080
95% L.C.L.ONLY	1	10422	16797	5392	5358	16785	9630
VALUES(HRS.)	2	5468	8019	1663	1595	6772	4515
@TEMPS. 1,2&3	3	1368	1774	508	458	1114	838
MEAN REG. LINE	3	1534	1919	550	508	1190	995
20,000 HOUR TEMP.INDEX		182	189	182	183	189	183
TEMP. VAL.(C) L.C.L.		180	188	179	180	188	181
30,000 HOUR TEMP.INDEX		177	184	176	177	185	179
TEMP. VAL.(C) L.C.L.		174	182	173	174	184	175
40,000 HOUR TEMP.INDEX		173	180	172	173	182	176
TEMP. VAL.(C) L.C.L.		170	179	169	169	181	172

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Table A1—Computer Readout Data, (Sheet 5) (Continued)

LISTING NUMBER		49	50	51	52	53	54
COMBINATIØN NUMBER		373	340	341	342	343	344
3 LØWEST	1	180	200	200	200	200	200
TEST	2	200	220	220	220	220	220
TEMPERATURES	3	220	240	240	240	240	240
LØG. AVG. LIFE	1	8554	19009	6228	4781	12471	6401
AT TEST	2	3262	3269	1505	1757	3269	2765
TEMP.(HRS.)	3	1092	1085	720	598	1085	917
95% L.C.L.ØNLY	1	8437	15447	4957	4635	11833	6027
VALUES(HRS.)	2	2985	3757	1754	1633	3386	2372
@TEMPS. 1,2&3	3	1082	878	570	582	1028	870
MEAN REG. LINE	3	1134	988	649	615	1060	973
20,000 HØUR	TEMP.INDEX	166	198	179	176	193	180
TEMP. VAL.(C)	L.C.L.	164	196	175	174	192	176
30,000 HØUR	TEMP.INDEX	159	193	173	170	187	173
TEMP. VAL.(C)	L.C.L.	157	191	168	167	186	168
40,000 HØUR	TEMP.INDEX	155	190	169	165	183	168
TEMP. VAL.(C)	L.C.L.	153	187	163	163	182	163

LISTING NUMBER		55	56	57	58	59	60
COMBINATION NUMBER		303	305	306	307	308	309
3 LØWEST	1	260	260	260	260	260	260
TEST	2	280	280	280	280	280	280
TEMPERATURES	3	300	300	300	300	300	300
LØG. AVG. LIFE	1	4544	12559	12559	9936	6573	3109
AT TEST	2	1836	2140	2464	1272	912	1540
TEMP.(HRS.)	3	528	720	720	528	528	720
95% L.C.L.ØNLY	1	4237	10065	11215	6590	3933	3087
VALUES(HRS.)	2	1525	2482	2658	1675	1286	1472
@TEMPS. 1,2&3	3	496	575	643	347	313	716
MEAN REG. LINE	3	567	652	684	439	419	734
20,000 HØUR TEMP.INDEX		237	253	253	249	241	217
TEMP. VAL.(C) L.C.L.		231	250	252	244	231	215
30,000 HØUR TEMP.INDEX		230	248	248	244	236	208
TEMP. VAL.(C) L.C.L.		224	245	247	238	225	206
40,000 HØUR TEMP.INDEX		226	244	245	241	232	202
TEMP. VAL.(C) L.C.L.		219	241	243	235	220	200

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Table A1—Computer Readout Data, (Sheet 6) (Continued)

LISTING NUMBER		61	62	63	64	65	66
COMBINATIØN NUMBER		310	361	362	259	260	261
3 LØWEST	1	260	220	220	200	200	200
TEST	2	280	240	240	220	220	220
TEMPERATURES	3	300	260	260	240	240	240
LØG. AVG. LIFE	1	2312	11975	14471	25783	10079	21533
AT TEST	2	996	9396	10452	8925	2802	5699
TEMP.(HRS.)	3	370	5300	5229	6475	1260	2184
95% L.C.L.ØNLY	1	2205	11587	13911	19838	8657	19361
VALUES(HRS.)	2	902	8076	8808	10641	3103	6120
@TEMPS. 1,2&3	3	355	5163	5065	4954	1079	1959
MEAN REG. LINE	3	384	5643	5611	5751	1176	2082
20,000 HØUR TEMP.INDEX		220	200	211	204	187	200
TEMP. VAL.(C) L.C.L.		215	191	204	200	184	199
30,000 HØUR TEMP.INDEX		213	184	197	193	180	194
TEMP. VAL.(C) L.C.L.		208	171	188	187	177	193
40,000 HØUR TEMP.INDEX		208	173	188	186	176	190
TEMP. VAL.(C) L.C.L.		203	158	177	178	172	188

LISTING NUMBER		67	68	69	70	71	72
COMBINATIØN NUMBER		262	263	264	265	266	283

LISTING NUMBER		67	68	69	70	71	72
COMBINATION NUMBER		262	263	264	265	266	283
3 LOWEST	1	200	200	200	200	200	200
TEST	2	220	220	220	220	240	220
TEMPERATURES	3	240	240	240	240	260	240
LOG. AVG. LIFE	1	17322	30343	12469	29134	15932	26846
AT TEST	2	5424	8825	2772	9228	1848	3156
TEMP.(HRS.)	3	2184	5316	1260	2856	624	1140
95% L.C.L.ONLY	1	16244	23585	9823	28908	15540	18338
VALUES(HRS.)	2	5663	10451	3253	8794	1717	4076
@TEMPS. 1,2&3	3	2045	4110	988	2840	628	772
MEAN REG. LINE	3	2122	4743	1131	2915	649	960
20,000 HOUR TEMP.INDEX		197	207	191	206	197	202
TEMP. VAL.(C) L.C.L.		196	204	188	206	196	199
30,000 HOUR TEMP.INDEX		190	198	185	200	190	197
TEMP. VAL.(C) L.C.L.		189	194	181	199	189	194
40,000 HOUR TEMP.INDEX		185	192	181	195	186	194
TEMP. VAL.(C) L.C.L.		184	187	176	195	185	190

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Table A1—Computer Readout Data, (Sheet 7) (Continued)

LISTING NUMBER		73	74	75	76	77	78
COMBINATIØN NUMBER		285	286	267	268	269	270
3 LØWEST	1	200	200	200	200	200	200
TEST	2	220	220	220	220	220	220
TEMPERATURES	3	240	240	240	240	240	240
LØG. AVG. LIFE	1	18731	9347	36960	9045	1492	18548
AT TEST	2	3156	1560	11307	2772	11996	3967
TEMP.(HRS.)	3	1140	478	4241	1092	4072	1848
95% L.C.L.ØNLY	1	14439	7657	34799	8489	14044	14234
VALUES(HRS.)	2	3715	1760	11586	2892	8244	4728
@TEMPS. 1,2&3	3	874	390	3990	1024	3898	1410
MEAN REG. LINE	3	1019	439	4156	1061	4772	1641
20,000 HØUR	TEMP.INDEX	198	190	210	186	196	197
TEMP. VAL.(C)	L.C.L.	195	188	210	185	186	194
30,000 HØUR	TEMP.INDEX	193	185	203	180	185	191
TEMP. VAL.(C)	L.C.L.	190	182	203	178	171	187
40,000 HØUR	TEMP.INDEX	189	182	198	175	177	186
TEMP. VAL.(C)	L.C.L.	186	179	198	174	161	182

LISTING NUMBER	79	80	81	82	83	84

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LISTING NUMBER		79	80	81	82	83	84
COMBINATIØN NUMBER		287	288	253	252	251	250
3 LØWEST TEST TEMPERATURES	1	200	200	200	200	200	200
	2	220	220	220	220	220	220
	3	240	240	240	240	240	240
LØG. AVG. LIFE AT TEST TEMP.(HRS.)	1	20855	6660	10735	20264	16073	7273
	2	3660	1140	3771	3010	3771	2763
	3	1476	550	1251	1909	1825	1326
95% L.C.L.ØNLY VALUES(HRS.) @TEMPS. 1,2&3	1	15798	4629	10636	12035	12597	6748
	2	4410	1447	3555	4264	4441	2871
	3	1111	379	1243	1121	1423	1229
MEAN REG. LINE	3	1302	468	1283	1509	1635	1289
20,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	199	182	190	197	195	179
	L.C.L.	196	176	189	190	191	176
30,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	193	177	183	191	188	171
	L.C.L.	190	170	182	182	184	168
40,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	190	173	179	187	183	165
	L.C.L.	186	165	178	177	179	163

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Table A1—Computer Readout Data, (Sheet 8) (Continued)

LISTING NUMBER		85	86	87	88	89	90
COMBINATION NUMBER		249	356	357	358	359	232
3 LOWEST	1	200	260	260	260	260	200
TEST	2	220	280	280	280	280	220
TEMPERATURES	3	240	300	300	300	300	240
LOG. AVG. LIFE	1	29826	6968	7596	9898	8553	13544
AT TEST	2	8439	1356	1524	2952	2364	8435
TEMP.(HRS.)	3	4009	528	624	1236	1200	4509
95% L.C.L.ONLY	1	25228	5534	5981	8919	6948	13375
VALUES(HRS.)	2	9442	1582	1789	3156	2712	7781
@TEMPS. 1,2&3	3	3379	418	489	1112	971	4469
MEAN REG. LINE	3	3717	476	560	1181	1094	4666
20,000 HOUR	TEMP.INDEX	206	244	245	247	243	188
TEMP. VAL.(C)	L.C.L.	205	240	241	245	238	186
30,000 HOUR	TEMP.INDEX	199	239	239	240	236	176
TEMP. VAL.(C)	L.C.L.	197	234	235	238	231	172
40,000 HOUR	TEMP.INDEX	193	235	235	235	231	167
TEMP. VAL.(C)	L.C.L.	191	230	230	233	225	163

LISTING NUMBER		91	92	93	94	95	96
COMBINATIØN NUMBER		233	234	235	236	295	302
3 LØWEST	1	200	200	200	200	200	200
TEST	2	220	220	220	220	220	220
TEMPERATURES	3	240	240	240	240	240	240
LØG. AVG. LIFE	1	6767	19535	25351	13532	8464	10960
AT TEST	2	3767	5531	5186	3767	4211	4467
TEMP.(HRS.)	3	1169	1844	920	1088	2184	1848
95% L.C.L.ØNLY	1	6457	19027	24905	13470	8448	10919
VALUES(HRS.)	2	2876	5627	4630	3667	4187	4363
@TEMPS. 1,2&3	3	1129	1795	909	1084	2181	1843
MEAN REG. LINE	3	1310	1823	965	1100	2189	1866
20,000 HØUR TEMP.INDEX		180	199	203	194	178	188
TEMP. VAL.(C) L.C.L.		173	199	203	194	178	188
30,000 HØUR TEMP.INDEX		172	193	199	189	168	180
TEMP. VAL.(C) L.C.L.		164	193	198	188	168	180
40,000 HØUR TEMP.INDEX		167	189	195	185	161	175
TEMP. VAL.(C) L.C.L.		158	189	195	184	161	174

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Table A1—Computer Readout Data, (Sheet 9) (Continued)

LISTING NUMBER		97	98	99	100	101	102
COMBINATIØN NUMBER		06	24	25	19	015	016
3 LØWEST	1	160	160	160	180	180	160
TEST	2	180	180	180	200	200	180
TEMPERATURES	3	200	200	200	220	220	200
LØG. AVG. LIFE	1	5040	4407	5538	27432	11573	18278
AT TEST	2	2614	1341	2424	5280	4835	4365
TEMP.(HRS.)	3	793	430	540	1714	648	2568
95% L.C.L.ØNLY	1	4796	4228	5258	23399	10660	13362
VALUES(HRS.)	2	2023	1297	1762	5853	2887	5380
@TEMPS. 1,2&3	3	764	413	521	1457	611	1864
MEAN REG. LINE	3	883	434	618	1597	806	2229
20,000 HØUR TEMP.INDEX		136	138	142	183	176	156
TEMP. VAL.(C) L.C.L.		129	136	137	182	170	151
30,000 HØUR TEMP.INDEX		129	132	137	178	171	149
TEMP. VAL.(C) L.C.L.		121	130	130	177	164	143
40,000 HØUR TEMP.INDEX		124	128	133	174	167	144
TEMP. VAL.(C) L.C.L.		116	126	126	173	160	137

LISTING NUMBER		103	104	105	106	107	108
COMBINATION NUMBER		86	87	89	90	91	271
3 LOWEST	1	240	240	240	240	240	160
TEST	2	260	260	260	280	260	180
TEMPERATURES	3	280	280	280	300	280	200
LOG. AVG. LIFE	1	12192	14172	12826	22939	12840	44107
AT TEST	2	3662	4335	4662	2346	5178	17159
TEMP.(HRS.)	3	1247	1606	1524	828	1774	7500
95% L.C.L.ONLY	1	11710	13240	12396	21775	12553	43451
VALUES(HRS.)	2	3669	4420	4288	2277	4687	17327
@TEMPS. 1,2&3	3	1198	1500	1478	797	1742	7366
MEAN REG. LINE	3	1238	1576	1574	833	1848	7450
20,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	232	234	233	242	233	177
	L.C.L.	231	233	231	241	231	177
30,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	226	227	226	236	225	168
	L.C.L.	225	226	224	235	223	168
40,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	221	223	221	231	220	162
	L.C.L.	220	221	219	230	218	162

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Table A1—Computer Readout Data, (Sheet 10) (Continued)

LISTING NUMBER		109	110	111	112	113	114
COMBINATIØN NUMBER		206	207	208	76	88	294
3 LØWEST	1	260	260	260	260	240	240
TEST	2	280	280	280	280	260	260
TEMPERATURES	3	300	300	300	300	280	280
LØG. AVG. LIFE	1	5921	5921	6928	5631	13420	6386
AT TEST	2	1824	2016	1824	1606	6682	2738
TEMP.(HRS.)	3	672	672	527	504	2615	711
95% L.C.L.ØNLY	1	5698	5884	6711	5465	13069	6156
VALUES(HRS.)	2	1872	1935	1805	1595	5889	2156
@TEMPS. 1,2&3	3	646	669	511	489	2560	692
MEAN REG. LINE	3	660	684	527	503	2755	786
20,000 HØUR TEMP.INDEX		240	240	245	241	232	223
TEMP. VAL.(C) L.C.L.		239	239	244	240	230	219
30,000 HØUR TEMP.INDEX		233	234	240	235	223	216
TEMP. VAL.(C) L.C.L.		233	233	239	234	220	212
40,000 HØUR TEMP.INDEX		229	229	236	231	217	212
TEMP. VAL.(C) L.C.L.		228	229	235	230	214	207

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LISTING NUMBER		115	116	117	118	119	120
COMBINATIØN NUMBER		279	280	281	282	289	301
3 LØWEST	1	200	200	200	200	200	200
TEST	2	220	220	220	220	220	220
TEMPERATURES	3	240	240	240	240	240	240
LØG. AVG. LIFE	1	10895	24313	11500	28115	40682	14927
AT TEST	2	3072	10986	1848	5448	8812	3760
TEMP.(HRS.)	3	1260	2460	766	624	6815	1428
95% L.C.L.ØNLY	1	9758	23113	8314	26922	25683	13226
VALUES(HRS.)	2	3307	7936	2290	4124	11999	4078
ØTEMPS. 1,2&3	3	1126	2374	550	605	4260	1262
MEAN REG. LINE	3	1199	2823	663	702	5535	1352
20,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	189	205	191	204	211	195
	L.C.L.	187	203	187	203	207	193
30,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	183	199	186	200	202	189
	L.C.L.	181	195	181	199	196	187
40,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	178	194	182	198	196	184
	L.C.L.	176	190	177	196	188	182

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Table A1—Computer Readout Data, (Sheet 11) (Continued)

LISTING NUMBER		121	122	123	124	125	126
COMBINATIØN NUMBER		298.	299	345	346	347	348
3 LØWEST	1	140	140	180	180	180	180
TEST	2	160	160	200	200	200	200
TEMPERATURES	3	180	180	220	220	220	220
LØG. AVG. LIFE	1	39040	45020	46304	10981	19970	33091
AT TEST	2	6207	6212	9995	5285	3773	2765
TEMP.(HRS.)	3	2016	1847	1421	1589	1253	1001
95% L.C.L.ØNLY	1	31299	34948	44510	10600	16766	19974
VALUES(HRS.)	2	7200	7246	7924	4216	4227	3881
@TEMPS. 1,2&3	3	1608	1426	1381	1551	1048	597
MEAN REG. LINE	3	1823	1658	1567	1749	1159	796
20,000 HØUR TEMP.INDEX		147	148	190	170	179	183
TEMP. VAL.(C) L.C.L.		146	147	189	167	178	180
30,000 HØUR TEMP.INDEX		142	144	186	163	174	179
TEMP. VAL.(C) L.C.L.		141	142	185	159	172	175
40,000 HØUR TEMP.INDEX		139	140	183	158	170	176
TEMP. VAL.(C) L.C.L.		137	138	181	153	168	172

LISTING NUMBER		127	128	129	130	131	132
COMBINATION NUMBER		349	350	351	352	353	354
3 LOWEST	1	180	200	200	200	200	200
TEST	2	200	240	220	220	220	220
TEMPERATURES	3	220	260	240	240	240	240
LOG. AVG. LIFE	1	35107	11302	3988	6991	11302	11302
AT TEST	2	5472	2532	1512	2520	4303	2520
TEMP.(HRS.)	3	1253	1535	720	816	2280	1020
95% L.C.L.ONLY	1	31989	10449	3682	6905	10207	9336
VALUES(HRS.)	2	5827	2663	1565	2327	4607	2865
@TEMPS. 1,2&3	3	1139	1396	664	809	2055	839
MEAN REG. LINE	3	1201	1461	700	844	2177	936
20,000 HOUR TEMP.INDEX		186	185	[illegible]	183	186	190
TEMP. VAL.(C) L.C.L.		185	183	164	182	184	188
30,000 HOUR TEMP.INDEX		181	175	160	177	178	184
TEMP. VAL.(C) L.C.L.		181	173	156	175	175	181
40,000 HOUR TEMP.INDEX		178	168	155	172	172	180
TEMP. VAL.(C) L.C.L.		177	166	151	171	169	177

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Table A1—Computer Readout Data, (Sheet 12) (Continued)

LISTING NUMBER		133	134	135	136	137	138
COMBINATIØN NUMBER		355	325	327	329	330	371
3 LØWEST	1	200	220	220	220	220	200
TEST	2	220	240	240	240	240	220
TEMPERATURES	3	240	260	260	260	260	240
LØG. AVG. LIFE	1	19328	10512	2520	3773	3773	14090
AT TEST	2	4975	7553	1260	1788	2772	2520
TEMP.(HRS.)	3	2364	2604	766	1512	1428	624
95% L.C.L.ØNLY	1	15788	10000	2345	3063	3680	13054
VALUES(HRS.)	2	5698	5470	1303	2056	2360	2652
ØTEMPS. 1,2&3	3	1923	2513	713	1222	1403	577
MEAN REG. LINE	3	2157	2985	747	1376	1528	603
20,000 HØUR TEMP.INDEX		198	207	163	158	165	196
TEMP. VAL.(C) L.C.L.		195	197	157	137	153	195
30,000 HØUR TEMP.INDEX		191	197	153	146	153	191
TEMP. VAL.(C) L.C.L.		188	185	147	123	139	190
40,000 HØUR TEMP.INDEX		186	190	146	138	145	188
TEMP. VAL.(C) L.C.L.		183	176	140	113	130	187

LISTING NUMBER		139	140	141	142	143	144
COMBINATION NUMBER		372	374	375	363	364	365
3 LOWEST	1	200	200	200	260	260	260
TEST	2	220	220	220	280	280	280
TEMPERATURES	3	240	240	240	300	300	300
LOG. AVG. LIFE	1	19418	27482	28682	11343	4177	7661
AT TEST	2	2836	1428	6694	1692	1692	2028
TEMP.(HRS.)	3	994	838	838	624	720	816
95% L.C.L.ONLY	1	14367	11458	27302	8344	4171	6729
VALUES(HRS.)	2	3430	2569	4892	2079	1682	2212
@TEMPS. 1,2&3	3	731	343	809	456	719	715
MEAN REG. LINE	3	872	564	957	543	722	770
20,000 HOUR TEMP.INDEX		198	200	205	251	229	244
TEMP. VAL.(C) L.C.L.		195	192	204	248	229	241
30,000 HOUR TEMP.INDEX		193	195	201	246	221	237
TEMP. VAL.(C) L.C.L.		190	187	199	242	221	235
40,000 HOUR TEMP.INDEX		190	192	198	243	216	233
TEMP. VAL.(C) L.C.L.		186	183	196	238	216	230

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Table A1—Computer Readout Data, (Sheet 13) (Continued)

LISTING NUMBER		145	146	147	148	149	150
COMBINATIØN NUMBER		217	237	238	239	240	241
3 LØWEST	1	240	200	200	200	200	200
TEST	2	260	220	220	220	220	220
TEMPERATURES	3	280	240	240	240	240	240
LØG. AVG. LIFE	1	24244	24878	17089	13099	8741	5962
AT TEST	2	6009	12351	4359	5031	2352	1680
TEMP.(HRS.)	3	1846	6695	1510	2009	1176	840
95% L.C.L.ØNLY	1	22439	24350	15639	12578	7111	4898
VALUES(HRS.)	2	6127	12427	4584	4891	2701	1903
@TEMPS. 1,2&3	3	1708	6552	1380	1932	953	687
MEAN REG. LINE	3	1809	6655	1456	2022	1071	771
20,000 HØUR TEMP.INDEX		243	206	197	192	184	177
TEMP. VAL.(C) L.C.L.		242	206	196	191	180	172
30,000 HØUR TEMP.INDEX		237	195	191	184	177	170
TEMP. VAL.(C) L.C.L.		236	194	190	183	172	165
40,000 HØUR TEMP.INDEX		233	187	187	179	172	166
TEMP. VAL.(C) L.C.L.		231	186	186	177	167	160

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		151	152	153	154	155	156
LISTING NUMBER		151	152	153	154	155	156
COMBINATION NUMBER		242	338	290	291	185	186
3 LØWEST	1	200	180	260	260	260	260
TEST	2	220	200	280	280	280	280
TEMPERATURES	3	240	220	300	300	300	300
LØG. AVG. LIFE	1	15680	10512	22600	22600	3612	4608
AT TEST	2	7383	3573	3317	8183	1248	1416
TEMP.(HRS.)	3	5649	2177	1343	2928	528	622
95% L.C.L.ØNLY	1	12972	8624	15881	22476	3433	4078
VALUES(HRS.)	2	8222	4081	4191	7901	1291	1517
@TEMPS. 1,2&3	3	4659	1778	938	2916	501	550
MEAN REG. LINE	3	5231	1990	1147	2972	516	592
20,000 HØUR TEMP.INDEX		189	164	260	262	228	233
TEMP. VAL.(C) L.C.L.		181	159	257	262	227	230
30,000 HØUR TEMP.INDEX		175	155	254	255	222	227
TEMP. VAL.(C) L.C.L.		165	149	251	255	220	223
40,000 HØUR TEMP.INDEX		166	149	251	250	217	222.
TEMP. VAL.(C) L.C.L.		154	142	246	250	215	218

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Table A1—Computer Readout Data, (Sheet 14) (Continued)

LISTING NUMBER		157	158	159	160	161	162
COMBINATIØN NUMBER		188	189	313	314	315	317
3 LØWEST	1	260	260	260	260	260	180
TEST	2	280	280	280	280	280	200
TEMPERATURES	3	300	300	300	300	300	220
LØG. AVG. LIFE	1	420	2680	6253	3945	9600	5560
AT TEST	2	152	1848	1237	863	888	708
TEMP.(HRS.)	3	24	720	574	432	624	360
95% L.C.L.ØNLY	1	396	2578	4615	2947	4579	3405
VALUES(HRS.)	2	104	1435	1502	1044	1459	980
@TEMPS. 1,2&3	3	23	700	421	321	293	218
MEAN REG. LINE	3	28	801	503	380	447	289
20,000 HØUR TEMP.INDEX		216	211	241	232	246	161
TEMP. VAL.(C) L.C.L.		207	196	235	225	234	153
30,000 HØUR TEMP.INDEX		211	201	235	226	241	156
TEMP. VAL.(C) L.C.L.		202	185	228	218	227	147
40,000 HØUR TEMP.INDEX		208	195	231	222	238	153
TEMP. VAL.(C) L.C.L.		198	178	224	214	222	143

LISTING NUMBER	163	164	165	166	167	168

LISTING NUMBER		163	164	165	166	167	168
COMBINATION NUMBER		300	254	255	256	257	258
3 LOWEST	1	200	200	200	200	200	200
TEST	2	220	220	220	220	220	220
TEMPERATURES	3	240	240	240	240	240	240
LOG. AVG. LIFE	1	14927	27894	4520	28455	22870	7919
AT TEST	2	4215	7589	1260	6937	3687	2259
TEMP.(HRS.)	3	1672	2161	648	4463	1573	1083
95% L.C.L.ONLY	1	13258	27783	3670	19867	16419	6654
VALUES(HRS.)	2	4462	7410	1443	8685	4605	2523
@TEMPS. 1,2&3	3	1482	2155	524	3094	1121	907
MEAN REG. LINE	3	1600	2183	591	3821	1354	1004
20,000 HOUR TEMP.INDEX		194	205	172	204	200	182
TEMP. VAL.(C) L.C.L.		193	205	166	200	197	179
30,000 HOUR TEMP.INDEX		188	199	165	196	194	175
TEMP. VAL.(C) L.C.L.		186	199	159	190	191	171
40,000 HOUR TEMP.INDEX		183	195	161	191	191	171
TEMP. VAL.(C) L.C.L.		181	195	154	183	186	166

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Table A1—Computer Readout Data, (Sheet 15) (Continued)

LISTING NUMBER		169	170	171	172	173	174
COMBINATION NUMBER		132	133	148	177	293	16
3 LØWEST	1	240	240	240	240	240	200
TEST	2	260	260	260	260	260	220
TEMPERATURES	3	280	280	280	280	280	240
LØG. AVG. LIFE	1	34015	21085	10080	24438	20907	29780
AT TEST	2	4284	5034	5037	8441	6932	1188
TEMP.(HRS.)	3	1926	2856	2808	3188	1848	431
95% L.C.L.ØNLY	1	21749	15536	9756	24315	20309	13630
VALUES(HRS.)	2	5780	6165	5101	8469	6089	2005
@TEMPS. 1,2&3	3	1221	2092	2717	3172	1805	194
MEAN REG. LINE	3	1575	2491	2778	3181	1949	303
20,000 HØUR TEMP.INDEX		244	239	221	244	241	201
TEMP. VAL.(C) L.C.L.		241	235	219	244	240	196
30,000 HØUR TEMP.INDEX		239	231	210	236	235	197
TEMP. VAL.(C) L.C.L.		235	226	208	236	234	192
40,000 HØUR TEMP.INDEX		236	226	203	231	231	195
TEMP. VAL.(C) L.C.L.		231	220	201	231	229	189

LISTING NUMBER		175	176	177	178	179	180
COMBINATION NUMBER		140	141	154	155	156	157
3 LOWEST	1	200	220	220	220	260	260
TEST	2	220	240	240	240	280	280
TEMPERATURES	3	240	260	260	260	300	300
LOG. AVG. LIFE	1	15983	8676	8692	5712	6474	6474
AT TEST	2	3288	5080	1176	840	2518	2518
TEMP.(HRS.)	3	816	252	497	420	1055	1008
95% L.C.L.ONLY	1	15572	7358	5755	3715	6305	6456
VALUES(HRS.)	2	3345	1749	1522	1121	2504	2478
@TEMPS. 1,2&3	3	795	224	326	271	1028	1006
MEAN REG. LINE	3	807	396	416	346	1053	1015
20,000 HOUR TEMP.INDEX		197	216	207	201	238	238
TEMP. VAL.(C) L.C.L.		197	205	202	193	237	238
30,000 HOUR TEMP.INDEX		192	211	203	195	230	231
TEMP. VAL.(C) L.C.L.		192	200	196	187	229	231
40,000 HOUR TEMP.INDEX		189	209	199	192	225	226
TEMP. VAL.(C) L.C.L.		188	196	192	183	224	226

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Table A1—Computer Readout Data, (Sheet 16) (Continued)

LISTING NUMBER		181	182	183	184	185	186
COMBINATION NUMBER		158	159	160	292	95	96
3 LOWEST	1	260	260	260	240	200	200
TEST	2	280	280	280	260	220	220
TEMPERATURES	3	300	300	300	280	240	240
LOG. AVG. LIFE	1	6474	7482	4272	18914	9714	6690
AT TEST	2	3190	2182	2854	5413	3456	2784
TEMP.(HRS.)	3	1151	1008	1104	16.8	768	563
95% L.C.L.ONLY	1	6305	6448	4116	18282	9355	6268
VALUES(HRS.)	2	2734	2411	2237	5539	2732	1981
@TEMPS. 1,2&3	3	1128	866	1074	1785	747	536
MEAN REG. LINE	3	1228	943	1223	1820	848	650
20,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	238	241	223	239	191	186
	L.C.L.	234	238	212	239	188	181
30,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	230	234	213	233	185	180
	L.C.L.	225	231	200	232	182	174
40,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	224	230	207	228	181	176
	L.C.L.	219	226	193	228	178	170

		187	188	189	190	191	192
LISTING NUMBER		187	188	189	190	191	192
COMBINATIØN NUMBER		97	108	109	57	84	85
3 LØWEST TEST TEMPERATURES	1	200	200	200	160	240	240
	2	220	220	220	180	260	260
	3	240	240	240	200	280	280
LØG. AVG. LIFE AT TEST TEMP.(HRS.)	1	6690	14112	15389	11040	22297	19271
	2	2784	3192	2346	8640	6282	6105
	3	456	382	120	4401	2762	2430
95% L.C.L.ØNLY VALUES(HRS.) @TEMPS. 1,2&3	1	6261	13327	14139	10711	19341	17913
	2	1818	2312	1383	7129	6900	6313
	3	435	366	113	4311	2389	2257
MEAN REG. LINE	3	546	438	150	4776	2592	2368
20,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	188	198	200	140	241	239
	L.C.L.	182	195	197	130	239	238
30,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	182	194	197	126	234	232
	L.C.L.	176	191	194	113	232	231
40,000 HØUR TEMP. VAL.(C)	TEMP.INDEX	179	191	194	116	229	227
	L.C.L.	171	188	191	102	226	225

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Table A1—Computer Readout Data, (Sheet 17) (Continued)

LISTING NUMBER		193	194	195	196	197	198
COMBINATION NUMBER		92	366	368	370	367	55
3 LOWEST	1	240	200	200	200	200	160
TEST	2	260	220	220	220	220	180
TEMPERATURES	3	280	240	240	240	240	200
LOG. AVG. LIFE	1	19444	30382	3471	10009	8665	20874
AT TEST	2	5778	9868	1091	1633	1964	8373
TEMP.(HRS.)	3	2262	988	409	678	647	5074
95% L.C.L.ONLY	1	18043	26562	3353	6965	7613	18255
VALUES(HRS.)	2	6075	5662	1116	1987	2086	9162
@TEMPS. 1,2&3	3	2096	886	395	469	568	4423
MEAN REG. LINE	3	2187	1241	403	588	618	4774
20,000 HOUR TEMP.INDEX		239	207	171	189	188	160
TEMP. VAL.(C) L.C.L.		238	204	171	184	186	157
30,000 HOUR TEMP.INDEX		232	202	165	184	182	149
TEMP. VAL.(C) L.C.L.		231	198	164	178	180	146
40,000 HOUR TEMP.INDEX		227	199	161	180	179	143
TEMP. VAL.(C) L.C.L.		226	195	160	173	176	139

LISTING NUMBER		199	200	201	202	203	204
COMBINATION NUMBER		56	101	102	103	104	105
3 LØWEST	1	160	200	200	200	200	200
TEST	2	180	220	220	220	220	220
TEMPERATURES	3	200	240	240	240	240	240
LØG. AVG. LIFE	1	20922	15557	18077	14045	6384	6027
AT TEST	2	9168	1846	3696	2514	336	958
TEMP.(HRS.)	3	5342	549	864	756	168	168
95% L.C.L.ØNLY	1	19197	11503	17964	11962	2851	5572
VALUES(HRS.)	2	9713	2257	3703	2780	577	916
@TEMPS. 1,2&3	3	4892	403	859	642	74	156
MEAN REG. LINE	3	5137	479	862	705	117	169
20,000 HØUR TEMP.INDEX		160	196	199	195	186	188
TEMP. VAL.(C) L.C.L.		159	193	199	193	176	187
30,000 HØUR TEMP.INDEX		150	192	194	190	182	184
TEMP. VAL.(C) L.C.L.		148	189	194	188	171	183
40,000 HØUR TEMP.INDEX		142	189	191	186	179	181
TEMP. VAL.(C) L.C.L.		140	185	190	184	168	180

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Table A1—Computer Readout Data, (Sheet 18) (Continued)

LISTING NUMBER		205	206	207	208	209	210
COMBINATIØN NUMBER		106	107	116	117	118	119
3 LØWEST	1	200	200	200	200	200	200
TEST	2	220	220	220	220	220	220
TEMPERATURES	3	240	240	240	240	240	240
LØG. AVG. LIFE	1	13391	11592	14045	16733	15389	4368
AT TEST	2	2436	2599	2145	3569	2481	624
TEMP.(HRS.)	3	549	636	600	575	504	132
95% L.C.L.ØNLY	1	12789	11431	11697	16194	14849	3967
VALUES(HRS.)	2	2478	2556	2425	3004	2540	666
@TEMPS. 1,2&3	3	524	627	498	561	486	120
MEAN REG. LINE	3	541	639	552	619	496	126
20,000 HØUR TEMP.INDEX		195	193	195	199	197	184
TEMP. VAL.(C) L.C.L.		195	193	193	198	197	183
30,000 HØUR TEMP.INDEX		191	188	190	194	193	180
TEMP. VAL.(C) L.C.L.		190	188	189	193	192	179
40,000 HØUR TEMP.INDEX		188	185	187	191	190	177
TEMP. VAL.(C) L.C.L.		187	184	185	190	189	176

LISTING NUMBER		211	212	213	214	215	216
COMBINATIØN NUMBER		120	121	122	130	131	136
3 LØWEST	1	200	200	200	200	180	200
TEST	2	220	220	220	220	200	220
TEMPERATURES	3	240	240	240	240	220	240
LØG. AVG. LIFE	1	4368	10299	11349	27656	15456	32976
AT TEST	2	766	2564	2384	3864	5040	4283
TEMP.(HRS.)	3	132	479	600	527	2184	1104
95% L.C.L.ØNLY	1	4264	9757	10417	27138	14309	26523
VALUES(HRS.)	2	714	2147	2371	3575	5308	4918
@TEMPS. 1,2&3	3	129	458	551	519	2018	884
MEAN REG. LINE	3	136	515	594	545	2109	1004
20,000 HØUR TEMP.INDEX		185	193	193	203	175	205
TEMP. VAL.(C) L.C.L.		184	191	192	203	174	203
30,000 HØUR TEMP.INDEX		181	188	188	200	167	200
TEMP. VAL.(C) L.C.L.		180	186	186	199	166	199
40,000 HØUR TEMP.INDEX		178	185	185	197	162	197
TEMP. VAL.(C) L.C.L.		177	182	183	196	161	195

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Table A1—Computer Readout Data, (Sheet 19) (Continued)

LISTING NUMBER		217	218	219	220	221	222
COMBINATIØN NUMBER		137	138	2	3	34	07
3 LØWEST	1	200	220	180	190	200	160
TEST	2	220	240	200	200	220	180
TEMPERATURES	3	240	260	220	220	240	200
LØG. AVG. LIFE	1	6989	6816	27724	15968	4788	4394
AT TEST	2	2952	1200	5065	5090	1380	924
TEMP.(HRS.)	3	959	132	1004	836	600	464
95% L.C.L.ØNLY	1	6805	6552	26695	14201	4224	2946
VALUES(HRS.)	2	2561	930	4889	5336	1501	1087
@TEMPS. 1,2&3	3	940	128	969	751	528	310
MEAN REG. LINE	3	1018	147	1015	814	567	406
20,000 HØUR TEMP.INDEX		182	211	184	187	175	135
TEMP. VAL.(C) L.C.L.		179	209	183	187	172	123
30,000 HØUR TEMP.INDEX		175	207	179	184	169	129
TEMP. VAL.(C) L.C.L.		172	205	179	183	166	116
40,000 HØUR TEMP.INDEX		171	205	176	181	164	125
TEMP. VAL.(C) L.C.L.		167	202	175	180	161	112

LISTING NUMBER		223	224	225	226	227	228
COMBINATION NUMBER		013	014	12	13	14	15
3 LOWEST	1	160	190	180	200	190	200
TEST	2	180	200	200	220	200	220
TEMPERATURES	3	200	220	220	240	220	240
LOG. AVG. LIFE	1	6014	12536	17443	5208	17270	6216
AT TEST	2	1579	6328	3454	1694	6048	1948
TEMP.(HRS.)	3	585	969	2200	554	2116	364
95% L.C.L.ONLY	1	5482	12507	11475	5096	13154	5931
VALUES(HRS.)	2	1680	5329	4553	1627	7006	1500
@TEMPS. 1,2&3	3	532	913	1434	543	1671	351
MEAN REG. LINE	3	561	1015	1824	562	1969	406
20,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	141	186	175	179	186	186
	L.C.L.	140	185	168	178	183	183
30,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	136	182	168	173	181	182
	L.C.L.	134	180	159	172	177	178
40,000 HOUR TEMP. VAL.(C)	TEMP.INDEX	132	179	163	169	177	178
	L.C.L.	130	177	154	167	173	174

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Table A1—Computer Readout Data, (Sheet 20) (Continued)

LISTING NUMBER		229	230	231	232	233	234
COMBINATIØN NUMBER		010	22	58	59	60	61
3 LØWEST	1	160	180	140	140	140	140
TEST	2	180	200	160	160	160	160
TEMPERATURES	3	200	220	180	180	180	180
LØG. AVG. LIFE	1	6104	5376	11238	13924	17620	19132
AT TEST	2	2306	3312	3192	3024	5069	7248
TEMP.(HRS.)	3	776	1524	994	840	3167	1164
95% L.C.L.ØNLY	1	6023	5259	10279	13316	13493	17700
VALUES(HRS.)	2	2119	2576	3073	3116	6062	4816
@TEMPS. 1,2&3	3	769	1501	912	802	2410	1100
MEAN REG. LINE	3	804	1618	997	823	2806	1383
20,000 HØUR TEMP.INDEX		140	146	132	135	135	141
TEMP. VAL.(C) L.C.L.		139	140	130	135	130	138
30,000 HØUR TEMP.INDEX		134	136	126	130	127	136
TEMP. VAL.(C) L.C.L.		132	129	123	130	121	132
40,000 HØUR TEMP.INDEX		129	129	122	127	121	133
TEMP. VAL.(C) L.C.L.		128	122	119	126	114	128

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LISTING NUMBER		235	236	237	238	239	240
COMBINATION NUMBER		62	80	81	017	018	022
3 LOWEST	1	140	140	140	160	160	160
TEST	2	160	160	160	180	180	180
TEMPERATURES	3	180	180	180	200	200	200
LOG. AVG. LIFE	1	6804	7582	17284	3024	5325	16018
AT TEST	2	2940	3350	8496	1500	3013	5124
TEMP.(HRS.)	3	1008	1428	3116	563	1192	1488
95% L.C.L.ONLY	1	6664	7527	16871	2673	4967	15722
VALUES(HRS.)	2	2580	3199	7297	1255	2497	4709
@TEMPS. 1,2&3	3	994	1421	3066	503	1123	1467
MEAN REG. LINE	3	1066	1456	3325	599	1283	1541
20,000 HOUR TEMP.INDEX		121	120	138	123	131	157
TEMP. VAL.(C) L.C.L.		119	119	136	111	122	156
30,000 HOUR TEMP.INDEX		114	112	130	116	123	151
TEMP. VAL.(C) L.C.L.		111	111	127	103	113	150
40,000 HOUR TEMP.INDEX		109	107	124	111	117	147
TEMP. VAL.(C) L.C.L.		106	106	121	97	106	146

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Table A1—Computer Readout Data, (Sheet 21) (Continued)

LISTING NUMBER		241	242	243	244	245	246
COMBINATION NUMBER		023	024	23	31	32	41
3 LOWEST	1	160	180	180	200	200	180
TEST	2	180	200	200	220	220	200
TEMPERATURES	3	200	220	220	240	240	220
LOG. AVG. LIFE	1	16704	25142	16464	6668	7752	8866
AT TEST	2	7392	7737	4909	1700	971	2637
TEMP.(HRS.)	3	2251	1944	2458	580	529	523
95% L.C.L.ONLY	1	16120	24651	13411	5806	4571	7193
VALUES(HRS.)	2	6107	6813	5425	1747	1375	2004
@TEMPS. 1,2&3	3	2194	1918	1996	505	308	430
MEAN REG. LINE	3	2440	2052	2278	561	418	573
20,000 HOUR TEMP.INDEX		158	184	175	184	185	171
TEMP. VAL.(C) L.C.L.		156	183	171	181	176	164
30,000 HOUR TEMP.INDEX		151	178	167	178	180	166
TEMP. VAL.(C) L.C.L.		148	177	163	175	170	158
40,000 HOUR TEMP.INDEX		146	174	162	174	176	162
TEMP. VAL.(C) L.C.L.		142	173	157	170	165	154

LISTING NUMBER		247	248	249	250	251	252
COMBINATIØN NUMBER		43	44	74	75	78	79
3 LØWEST	1	180	190	140	140	200	200
TEST	2	200	200	160	160	220	220
TEMPERATURES	3	220	220	180	180	240	240
LØG. AVG. LIFE	1	10330	4024	8199	7548	14098	15600
AT TEST	2	2049	1800	1713	1797	5356	5411
TEMP.(HRS.)	3	318	120	634	371	456	499
95% L.C.L.ØNLY	1	10077	3558	6892	7411	12705	14212
VALUES(HRS.)	2	1745	1208	1925	1601	2744	2972
@TEMPS. 1,2&3	3	313	92	531	366	424	467
MEAN REG. LINE	3	340	132	586	390	605	643
20,000 HØUR	TEMP.INDEX	174	179	127	129	199	200
TEMP. VAL.(C)	L.C.L.	173	174	124	128	194	196
30,000 HØUR	TEMP.INDEX	170	176	121	124	195	196
TEMP. VAL.(C)	L.C.L.	168	171	119	123	189	190
40,000 HØUR	TEMP.INDEX	167	174	118	121	192	192
TEMP. VAL.(C)	L.C.L.	165	168	115	120	185	187

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Table A1—Computer Readout Data, (Sheet 22) (Continued)

LISTING NUMBER		253	254
COMBINATION NUMBER		128	129
3 LOWEST	1	200	200
TEST	2	220	220
TEMPERATURES	3	240	240
LOG. AVG. LIFE	1	8980	5712
AT TEST	2	1510	2009
TEMP.(HRS.)	3	185	408
95% L.C.L.ONLY	1	8514	5440
VALUES(HRS.)	2	1234	1532
@TEMPS. 1,2&3	3	177	393
MEAN REG. LINE	3	201	457
20,000 HOUR TEMP.INDEX		193	184
TEMP. VAL.(C) L.C.L.		192	180
30,000 HOUR TEMP.INDEX		189	179
TEMP. VAL.(C) L.C.L.		188	175
40,000 HOUR TEMP.INDEX		187	176
TEMP. VAL.(C) L.C.L.		185	171

***** END OF DATA *****

TIME: 77.45 SECS.

TEMP. VAL.(C) L.C.L. 188 175

40,000 HOUR TEMP.INDEX	187	176
TEMP. VAL.(C) L.C.L.	185	171

***** END OF DATA *****

TIME: 77.45 SECS.

2

Index to Computer Data Sheets (Table A2) and Motorette System Identification

Sheet Number	Listing Number	System Number	Magnet Wire	Varnish	Phase	Ground	Slot Wedge
23	1	1	A	1A	Cambric	Fish Paper	GMG
23	2	2	A	1A	Org. Varn. Glass	Org. Varn. Mica-Glass	GMG
23	3	3	A	1A	Cambric	Rope Acetate	GMG
23	4	15	A	2B	Mylar Film	Mylar-Paper	GMG
23	5	29	A	2A	Org. Varn. Glass	Org. Varn. Mica-Glass	GMG
23	6	41	A	2D	Org. Varn. Glass	Org. Varn. Mica-Glass	GMG
23	7	42	A	2E	Org. Varn. Glass	Org. Varn Mica-Glass	GMG
23	8	95	A	2B	Mylar Film	Mylar Film	GMG
23	9	98	A	2E	263-3F	263-3F	GMG
23	10	99	A	2E	Copaco Rag Paper	Copaco Rag Paper	GMG
23	11	8	Y-3	10A	Sil. Varn. Glass	Mica Mat Glass	GSG
23	12	12	B-2	2A	Org. Varn. Glass	Org. Mica Glass	GMG
24	13	36	C-5	10A	Epoxy Var. Mica-Glass	Org. Var. Mica-Glass	GMG
24	14	14		2A	Org. Var. Glass	Org. Var. Mica-Glass	GMG
24	15	20	Z-1	2A	Epoxy Mica Mat-Glass	Epoxy Mica Mat-Glass	GMG
24	16	26	Z-1	6A	Epoxy Mica Mat-Glass	Epoxy Mica Mat-Glass	GMG
24	17	49	Z-3	2C	Org. Var. Mica-Glass	Org. Var. Mica-Glass	GMG
24	18	21	Y-1	6A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG

Index to Computer Data Sheets (Table A2) and Motorette System Identification (Continued)

Sheet Number	Listing Number	System Number	Magnet Wire	Varnish	Phase	Ground	Slot Wedge
24	19	22	Y-1	10A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
24	20	33	Y-2	10A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GMG
24	21	19	B-1	2A	Org. Var. Glass	Org. Var. Mica-Glass	GMG
24	22	23	B-1	3A	Org. Var. Glass	Org. Var. Mica-Glass	GMG
24	23	32	*B-1	3A	Org. Var. Glass	Org. Var Mica-Glass	GMG
24	24	34	B-1	2A	Polyester Fiber Mat	Org. Var. Mica-Glass	GMG
25	25	40	B-1	4A	Org. Var. Mica-Glass	Org. Var. Mica-Glass	GMG
25	26	30	B-3	2A	Org. Var. Glass	Org. Var. Mica-Glass	GMG
25	27	31	B-3	4D	Org. Var. Glass	Org. Var. Mica-Glass	GMG
25	28	29	C-2	4E	Org. Var. Glass	Org. Var. Mica-Glass	GMG
25	29	37	B-5	2A	Copalum (20 m)	Glass-Mica Glass (12 m)	GMG
25	30	53	R	15A	6105C	6105C	64051 (Dupont)
25	31	67	C-1	4B	Polyester Var. Glass	Polyester Var. Mica Mat	GMG
25	32	68	D-1	NONE	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
25	33	48	C-1	4A	Org. Var. Mica-Glass	Org. Var. Mica-Glass	GMG
25	34	51	H-3	10A	2 Sil. Mica Glass	2 Sil. Mica Glass	Silicone Glass
25	35	52	H-1	13D	1 HT-1 Paper	1 HT-1 Paper	Molded Glass

*#18 AWG

Index to Computer Data Sheets (Table A2) and Motorette System Identification (Continued)

Sheet Number	Listing Number	System Number	Magnet Wire	Varnish	Phase	Ground	Slot Wedge
25	36	54	H-1	13D	(ML Var. Gl.) 6507 (7 m)	(ML Var. Gl.) 6507 (15 m)	64051 (Dupont)
26	37	59	H-1	13D	(ML Var. Gl.) 6507 (7 m)	(ML Var. Gl.) 6507 (7 m)	GSG
26	38	69	H-1	13B	"H" Film (7 m)	"H" Film (15 m)	GSG
26	39	70	H-1	8A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
26	40	71	H-1	8A	Doryl Glass	Doryl Glass	GSG
26	41	73	H-1	4E	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
26	42	74	H-1	6B	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
26	43	76	H-1	10A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
26	44	80	H-1	13C	Nomex (HT-1) Paper	Nomex (HT-1) Paper	GSG
26	45	84	H-1	10A	Nomex-H Film-Nomex	Nomex-H Film-Nomex	GSG
26	46	88	H-1	10A	Nomex (HT-1)	Nomex (HT-1)	GSG
26	47	94	H-1	10A	Astrotherm 240-21	Astrotherm 240-21	GSG
26	48	56	D-3	4A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
27	49	57	D-3	10A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GMG
27	50	85	D-3	4E	Mylar xm-633 (2 ply)	Mylar xm-633 (2 ply)	GSG
27	51	86	D-3	4E	633 (1 ply)	633 (1 ply)	GSG
27	52	82	I	10A	Nomex (HT-1) Paper	Nomex (HT-1) Paper	GSG

Index to Computer Data Sheets (Table A2) and Motorette System Identification (Continued)

Sheet Number	Listing Number	System Number	Magnet Wire	Varnish	Phase	Ground	Slot Wedge
27	53	100	L-1	NONE	Nomex (7 m)	Nomex (14 m)	GSG
27	54	72	F-2	10A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
27	55	87	F-1	4E	Cfam 150 P 1m/5m/5m	Cfam 150 P 3m/5m/3m	GSG
27	56	58	D-2	10A	Sil. Var. Mica-Glass	Sil. Var. Mica-Glass	GSG
27	57	60	D-2	4E	Dac.-Mylar-Dac.	Dac.-Mylar-Dac.	GSG
27	58	75	D-2	4E	Polyester Mat 2542	Polyester Mat 2542	GSG
27	59	77	D-2	4E	Estermat Dm 70-353	Estermat Dm 70-353	CSG
27	60	78	D-2	5C	Estermat Dm 70-353	Estermat Dm 70-353	GSG
28	61	79	D-2	5D	Estermat Dm 70-353	Estermat Dm 70-353	GSG
28	62	81	D-2	4E	Duroid 2307	Duroid 2307	Duroid 2310

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Table A2—Computer Readout Data, (Sheet 23)

LISTING NUMBER		1	2	3	4	5	6
SYSTEM NUMBER		1	2	3	15	29	41
3 LØWEST	1	150	135	160	145	150	145
TEST	2	160	160	180	160	160	160
TEMPERATURES	3	180	180	200	180	180	180
LØG. AVG. LIFE	1	2118	8642	2403	4360	3926	3170
AT TEST	2	1560	2534	914	1573	540	1221
TEMP.(HRS.)	3	828	956	299	935	224	628
95% L.C.L.ØNLY	1	2119	8467	2313	3353	1759	2610
VALUES(HRS.)	2	1533	2418	821	1860	863	1366
@TEMPS. 1,2&3	3	824	945	289	729	113	522
MEAN REG. LINE	3	832	976	312	848	179	587
20,000 HØUR	TEMP.INDEX	93	120	126	113	130	109
TEMP. VAL.(C)	L.C.L.	91	119	123	103	117	103
30,000 HØUR	TEMP.INDEX	84	113	120	105	126	103
TEMP. VAL.(C)	L.C.L.	83	112	116	95	112	95
40,000 HØUR	TEMP.INDEX	78	109	116	101	123	98
TEMP. VAL.(C)	L.C.L.	77	108	112	89	108	90

TEMP. VAL.(C) L.C.L.		77	108	112	89	108	90

LISTING NUMBER		7	8	9	10	11	12
SYSTEM NUMBER		42	95	98	99	8	12
3 LØWEST TEST TEMPERATURES	1	145	140	160	140	240	160
	2	160	160	180	160	260	180
	3	180	180	200	180	280	200
LØG. AVG. LIFE AT TEST TEMP.(HRS.)	1	3689	5600	3236	6500	2274	4760
	2	1722	3058	1249	2184	680	1796
	3	921	1606	479	1020	259	720
95% L.C.L.ØNLY VALUES(HRS.) @TEMPS. 1,2&3	1	3123	5486	3173	5921	2096	4603
	2	1812	2925	1198	2325	704	1760
	3	781	1577	471	927	239	697
MEAN REG. LINE	3	883	1633	487	978	252	723
20,000 HØUR TEMP.INDEX		108	106	128	118	205	134
TEMP. VAL.(C) L.C.L.		99	104	126	116	203	132
30,000 HØUR TEMP.INDEX		100	97	121	111	199	127
TEMP. VAL.(C) L.C.L.		90	93	120	109	196	125
40,000 HØUR TEMP.INDEX		95	90	117	106	195	122
TEMP. VAL.(C) L.C.L.		84	87	115	104	192	120

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Table A2—Computer Readout Data, (Sheet 24) (Continued)

LISTING NUMBER		13	14	15	16	17	18
SYSTEM NUMBER		36	14	20	26	49	21
3 LOWEST	1	190	160	160	160	160	200
TEST	2	200	180	180	180	180	220
TEMPERATURES	3	220	200	200	200	200	240
LOG. AVG. LIFE	1	16500	5680	5302	6965	8256	5440
AT TEST	2	5342	2200	2790	3793	1478	1400
TEMP.(HRS.)	3	915	552	1245	2400	585	382
95% L.C.L.ONLY	1	14510	5484	5058	6651	6222	5421
VALUES(HRS.)	2	5594	1766	2513	3886	1745	1372
@TEMPS. 1,2&3	3	812	539	1194	2290	439	381
MEAN REG. LINE	3	890	606	1296	2357	520	385
20,000 HOUR TEMP.INDEX		188	142	130	126	147	183
TEMP. VAL.(C) L.C.L.		187	139	124	124	142	182
30,000 HOUR TEMP.INDEX		184	136	121	115	142	178
TEMP. VAL.(C) L.C.L.		183	132	115	112	137	177
40,000 HOUR TEMP.INDEX		181	132	115	107	138	174
TEMP. VAL.(C) L.C.L.		180	128	108	104	133	174

LISTING NUMBER		19	20	21	22	23	24
SYSTEM NUMBER		22	33	19	23	32	34
3 LOWEST	1	200	200	180	180	160	160
TEST	2	220	220	200	200	180	180
TEMPERATURES	3	240	240	220	220	200	200

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LISTING NUMBER		19	20	21	22	23	24
SYSTEM NUMBER		22	33	19	23	32	34
3 LØWEST	1	200	200	180	180	160	160
TEST	2	220	220	200	200	180	180
TEMPERATURES	3	240	240	220	220	200	200
LØG. AVG. LIFE	1	6280	5666	4128	6400	6934	16897
AT TEST	2	1670	1130	1750	2070	5350	8530
TEMP.(HRS.)	3	310	263	741	774	2900	1400
95% L.C.L.ØNLY	1	6046	5341	4058	6268	6674	15501
VALUES(HRS.)	2	1368	1120	1691	2100	4538	5138
ØTEMPS. 1,2&3	3	301	248	730	758	2814	1317
MEAN REG. LINE	3	337	262	751	767	3104	1735
20,000 HØUR TEMP.INDEX		187	185	149	161	122	160
TEMP. VAL.(C) L.C.L.		185	184	147	160	108	155
30,000 HØUR TEMP.INDEX		182	181	141	154	108	154
TEMP. VAL.(C) L.C.L.		180	180	140	154	92	148
40,000 HØUR TEMP.INDEX		179	178	136	150	99	150
TEMP. VAL.(C) L.C.L.		176	176	135	150	81	143

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Table A2—Computer Readout Data, (Sheet 25) (Continued)

LISTING NUMBER		25	26	27	28	29	30
SYSTEM NUMBER		40	30	31	39	37	53
3 LØWEST	1	180	160	160	180	180	140
TEST	2	200	180	180	200	200	160
TEMPERATURES	3	220	200	200	220	220	180
LØG. AVG. LIFE	1	7887	13368	22104	7791	6489	8427
AT TEST	2	3245	5064	7211	3530	4540	730
TEMP.(HRS.)	3	953	2676	3145	540	1129	430
95% L.C.L.ØNLY	1	7182	12049	18342	6866	5953	4252
VALUES(HRS.)	2	2665	5410	7392	2126	2870	1153
*TEMPS. 1,2&3	3	877	2407	2682	488	1059	214
MEAN REG. LINE	3	1027	2557	3035	665	1369	316
20,000 HØUR TEMP.INDEX		165	150	161	170	161	127
TEMP. VAL.(C) L.C.L.		160	148	159	162	147	117
30,000 HØUR TEMP.INDEX		159	142	154	165	153	122
TEMP. VAL.(C) L.C.L.		153	139	150	155	137	111
40,000 HØUR TEMP.INDEX		154	136	149	161	148	119
TEMP. VAL.(C) L.C.L.		148	133	145	151	130	107

LISTING NUMBER	31	32	33	34	35	36
SYSTEM NUMBER	67	68	48	51	52	54

LISTING NUMBER		31	32	33	34	35	36
SYSTEM NUMBER		67	68	48	51	52	54
3 LØWEST	1	200	200	200	260	240	240
TEST	2	220	220	220	280	260	260
TEMPERATURES	3	240	240	240	300	280	280
LØG. AVG. LIFE	1	8956	5017	9655	10093	9538	3500
AT TEST	2	809	1137	1985	4046	3049	2100
TEMP.(HRS.)	3	209	312	576	870	1196	765
95% L.C.L.ØNLY	1	6294	4867	8838	9565	8899	3380
VALUES(HRS.)	2	1017	1160	2106	3015	3128	1673
@TEMPS. 1,2&3	3	146	302	526	835	1116	746
MEAN REG. LINE	3	179	308	553	984	1170	842
20,000 HØUR TEMP.INDEX		191	182	190	251	227	202
TEMP. VAL.(C) L.C.L.		188	182	189	247	225	193
30,000 HØUR TEMP.INDEX		187	177	185	246	220	194
TEMP. VAL.(C) L.C.L.		184	177	184	241	218	184
40,000 HØUR TEMP.INDEX		184	174	182	241	215	188
TEMP. VAL.(C) L.C.L.		181	173	180	236	213	177

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Table A2—Computer Readout Data, (Sheet 26) (Continued)

LISTING NUMBER		37	38	39	40	41	42
SYSTEM NUMBER		59	69	70	71	73	74
3 LOWEST	1	260	260	240	240	260	260
TEST	2	280	280	260	260	280	280
TEMPERATURES	3	300	300	280	280	300	300
LOG. AVG. LIFE	1	6515	6662	4192	3497	9000	5347
AT TEST	2	2431	2292	985	426	2110	800
TEMP.(HRS.)	3	1365	755	263	206	585	266
95% L.C.L.ONLY	1	5666	6610	4154	2147	8485	3950
VALUES(HRS.)	2	2658	2180	991	591	2124	943
@TEMPS. 1,243	3	1184	751	261	125	552	196
MEAN REG. LINE	3	1285	771	262	165	578	236
20,000 HOUR TEMP.INDEX		233	242	220	216	249	243
TEMP. VAL.(C) L.C.L.		229	241	220	207	248	238
30,000 HOUR TEMP.INDEX		225	236	215	211	244	238
TEMP. VAL.(C) L.C.L.		220	235	215	201	243	233
40,000 HOUR TEMP.INDEX		219	231	211	208	240	235
TEMP. VAL.(C) L.C.L.		213	230	211	197	239	229

30,000 HØUR TEMP.INDEX		225	236	215	211	244	238
TEMP. VAL.(C) L.C.L.		220	235	215	201	243	233
40,000 HØUR TEMP.INDEX		219	231	211	208	240	235
TEMP. VAL.(C) L.C.L.		213	230	211	197	239	229

LISTING NUMBER		43	44	45	46	47	48
SYSTEM NUMBER		76	80	84	88	94	56
3 LØWEST	1	260	240	260	260	260	200
TEST	2	280	260	280	280	280	220
TEMPERATURES	3	300	280	300	300	300	240
LØG. AVG. LIFE	1	14593	9371	8401	8676	11323	7507
AT TEST	2	2975	5513	3232	2868	1735	910
TEMP.(HRS.)	3	1057	3543	1200	1209	995	264
95% L.C.L.ØNLY	1	12229	9186	7974	8076	7058	5660
VALUES(HRS.)	2	3349	5587	3047	2992	2382	1100
@TEMPS. 1,2&3	3	883	3472	1142	1124	615	198
MEAN REG. LINE	3	976	3511	1222	1174	804	232
20,000 HØUR TEMP.INDEX		255	212	244	244	249	188
TEMP. VAL.(C) L.C.L.		253	211	242	243	241	185
30,000 HØUR TEMP.INDEX		249	199	237	237	243	184
TEMP. VAL.(C) L.C.L.		247	198	234	235	234	181
40,000 HØUR TEMP.INDEX		245	190	232	232	239	181
TEMP. VAL.(C) L.C.L.		243	188	229	230	229	178

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Table A2—Computer Readout Data, (Sheet 27) (Continued)

LISTING NUMBER		49	50	51	52	53	54
SYSTEM NUMBER		57	85	86	82	100	72
3 LØWEST	1	180	180	160	260	220	220
TEST	2	200	200	180	280	240	240
TEMPERATURES	3	220	220	200	300	260	260
LØG. AVG. LIFE	1	13934	9956	12323	5589	9300	4410
AT TEST	2	5640	4005	8638	1942	3342	262
TEMP.(HRS.)	3	522	696	3410	538	1428	240
95% L.C.L.ØNLY	1	12495	9363	11031	5321	8950	1614
VALUES(HRS.)	2	2908	2713	6516	1693	3429	514
@TEMPS. 1,2&3	3	483	667	3098	515	1373	86
MEAN REG. LINE	3	691	821	3806	568	1403	152
20,000 HØUR TEMP.INDEX		179	173	149	241	205	197
TEMP. VAL.(C) L.C.L.		173	168	137	238	204	175
30,000 HØUR TEMP.INDEX		174	167	138	235	198	192
TEMP. VAL.(C) L.C.L.		168	162	122	232	197	168
40,000 HØUR TEMP.INDEX		171	163	131	231	193	189
TEMP. VAL.(C) L.C.L.		164	158	113	227	192	164

TEMP. VAL.(C) L.C.L.		168	162	122	[illegible]	197	[illegible]
40,000 HOUR TEMP.INDEX		171	163	131	231	193	189
TEMP. VAL.(C) L.C.L.		164	158	113	227	192	164

LISTING NUMBER		55	56	57	58	59	60
SYSTEM NUMBER		87	58	60	75	77	78
3 LOWEST	1	190	200	190	200	190	190
TEST	2	200	220	200	220	200	200
TEMPERATURES	3	220	240	220	240	220	220
LOG. AVG. LIFE	1	6378	7202	13849	7078	11905	14441
AT TEST	2	2154	390	4152	1158	4375	2948
TEMP.(HRS.)	3	480	156	390	239	1236	1239
95% L.C.L.ONLY	1	5313	3552	13004	6527	10003	7905
VALUES(HRS.)	2	2323	627	3922	1168	4845	4178
@TEMPS. 1,2&3	3	407	76	358	220	1066	741
MEAN REG. LINE	3	460	113	393	235	1178	1050
20,000 HOUR TEMP.INDEX		177	188	187	189	182	182
TEMP. VAL.(C) L.C.L.		175	180	186	188	181	175
30,000 HOUR TEMP.INDEX		173	184	184	185	177	178
TEMP. VAL.(C) L.C.L.		170	176	183	183	175	169
40,000 HOUR TEMP.INDEX		170	182	182	182	174	174
TEMP. VAL.(C) L.C.L.		167	173	181	180	172	165

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Table A2—Computer Readout Data, (Sheet 28) (Continued)

LISTING NUMBER		61	62
SYSTEM NUMBER		79	81
3 LOWEST	1	190	190
TEST	2	200	200
TEMPERATURES	3	220	220
LOG. AVG. LIFE	1	10691	8101
AT TEST	2	5177	4375
TEMP.(HRS.)	3	1824	1064
95% L.C.L.ONLY	1	9300	8123
VALUES(HRS.)	2	5342	4068
VTEMPS. 1,2&3	3	1593	1041
MEAN REG. LINE	3	1779	1086
20,000 HOUR TEMP.INDEX		179	178
TEMP. VAL.(C) L.C.L.		177	178
30,000 HOUR TEMP.INDEX		173	173
TEMP. VAL.(C) L.C.L.		170	172
40,000 HOUR TEMP.INDEX		169	169
TEMP. VAL.(C) L.C.L.		165	168

***** END OF DATA *****

TIME: 20.17 SECS.

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MEAN REG. LINE      3              1779     1086

 20,000 HOUR   TEMP.INDEX          179      178
TEMP. VAL.( C)  L.C.L.             177      178

 30,000 HOUR   TEMP.INDEX          173      173
TEMP. VAL.( C)  L.C.L.             170      172

 40,000 HOUR   TEMP.INDEX          169      169
TEMP. VAL.( C)  L.C.L.             165      163

***** END OF DATA *****


TIME:  20.17 SECS.
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Table A3—Generic Name Index for Magnet Wire Insulation

Index No.	Generic Name
A	Polyvinyl Formal
B-1 thru B-7	Polyester
C-1 thru C-5	Modified Polyester
D-1, D-2, D-3	Modified Polyester with Linear Polyester Topcoat
E-1, E-2	Tris-Polyester
F-1, F-2	Tris-Polyester with Linear Polyester Topcoat
G-1 thru G-8	Tris-Polyester with Linear Polyamideimide Topcoat
H-1 thru H-11	Polyimide
I	Amide-Imide
J-1, J-2	Nylon
K-1, K-2, K-3	Polyester/Nylon
L-1 thru L-5	Bondable
M-1, M-2	Aromatic Polyester Amide-Imide
N-1, N-2	Aromatic Polyester Amide-Imide with PolyAmide-imide Topcoat
O	Tris-Polyester with Amide-Imide Topcoat
P-1, P-2, P-3	Polyesterimide
Q	Polyester-Amide
R	Acrylic
S	Single Polyester Film/Single Polyester-glass/Glass/Silicone varnish
T	Single Polyester Film/Glass/Double Polyester-glass
U	Single Polyester Film/Dble Polyester-glass/Silicone Varnished
V	Polyester Film/Polyester-glass Fiber
W	Polyester Film/Dble Polyester-glass Fiber
X	Bare (no film)/Single Polyester-glass Fiber
Y-1, Y-2, Y-3	Silicone Modified Polyester
Z-1, Z-2, Z-3	Epoxy

Table A4—Generic Name Index for Insulating Varnishes

Index No.	Generic Name
1A	Oleoresinous, Organic
2A thru 2F	Oil Modified Phenolic
3A	Oil Modified Alkyd
4A thru 4F	Modified Polyester
5A thru 5E	Phenolic Modified Polyester
6A, 6B, 6C	Silicone Modified Polyester
7A	Tris-Polyester
8A	Diphenyl Oxide Polymer
9A	Unmodified Epoxy
10A, 10B	Silicone
11A	Experimental Solventless
12A	Solventless, Two Component Epoxy
13A, 13B, 13C, 13D	Polyimide (12% solids)
14A	Amide-Imide
15A	Acrylic